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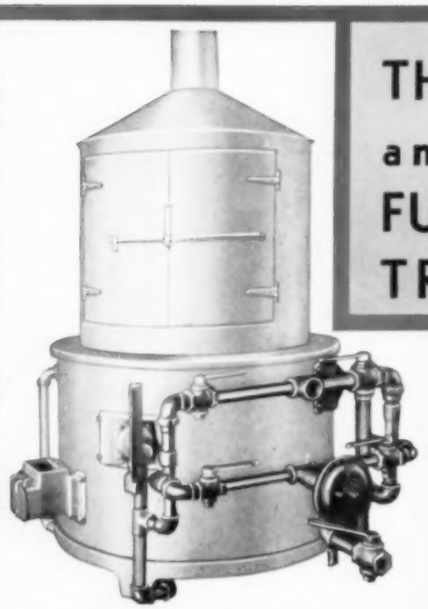
Metal PROGRESS



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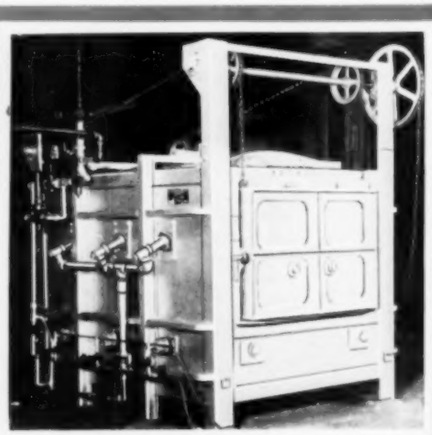
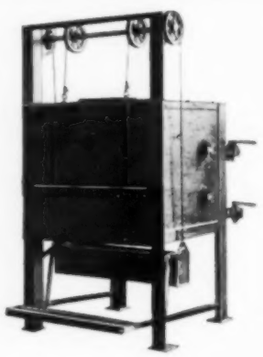
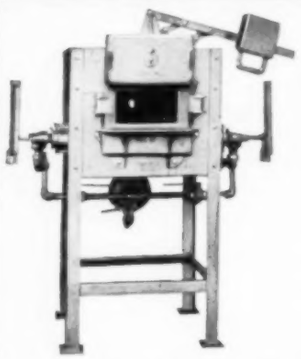


SC Large Oven Furnace for heat treating in a large foundry.



SC High Speed Controlled Atmosphere Muffle Furnace used primarily for heat treating tools



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For any Heat-Treating Operation

Published by the American Society for Metals

Metal Progress

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Published and copyrighted, 1934, by the American Society for Metals, 7016 Euclid Avenue, Cleveland, Ohio. Issued monthly, subscription $5 a year, current copies 50c. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, O., under the Act of March 3, 1870. American Society for Metals is not responsible for statements or opinions printed in this publication. Editorials are written by the editor and represent his views. He is also sponsor for unsigned and staff articles. . . . Ernest E. Thum, Editor.

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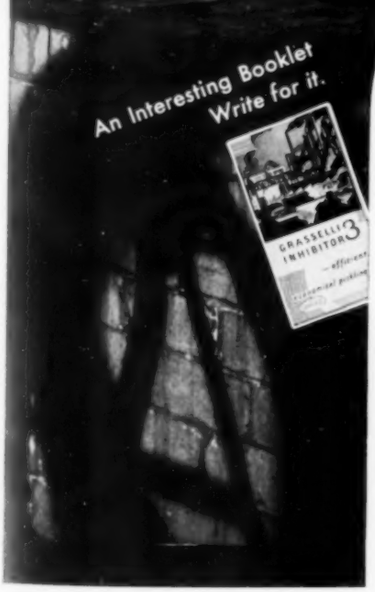

FIGURES
WHICH MAY INTEREST YOU

These figures, representing regular production over a period of months, have been obtained from different plants in this country and they cover the acid consumption, per ton of material pickled, found in those plants:

	ACID USED °Be.	Pounds
Breakdowns	60	28-30
Black plate pickler, tin plate mill	60	68-72
Butt weld pipe, silica bottom furnaces, straightened cold, ½" to 5"	60	33-35
Alloy and straight carbon, annealed, normalized, heat-treated automobile forgings, all kinds	66	19-21
Rod and wire mill, large tonnage; pickling basic, bessemer, rephosphorized, 65-75 carbon patent anneal rod	60	39-40

Representing average mills, average plant and equipment conditions, simple pickling room control and *the use of a good inhibitor*, we believe these figures prove the economy of efficient, economical pickling . . . Would your plant be in this list? If not, Grasselli 3 Powder Inhibitor and Grasselli Service can be of benefit to you.

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Steel and Alloys—the Basis of All Industry

A photographic impression by Rittase

Annual Convention breaks all records

Notable in many ways was the Annual Convention and 16th National Metal Congress. The latter was especially attractive in beauty and variety of exhibits—like a little section of the Chicago Fair. Reports from National Officers prove that the Society is climbing rapidly back to pre-depression size and enthusiasm. Memorial lecture and technical sessions attain expected quality.

FOR the first time in its history the American Society for Metals held its convention and the Sixteenth National Metal Exposition in New York City. Whereas it has been the policy to hold the meetings alternately in the East and in the West, New York has never before had an acceptable exhibit hall of sufficient area on a single floor to hold the exposition. This situation has now been corrected in "Commerce Hall" — the entire second floor of the Port of New York Authority's Inland Terminal, which has every convenience for industrial exhibits on a grand scale.

Anyone fortunate enough to have been able to attend will vouch for the wisdom of holding such an exposition at this time. The result passed all expectations, not only as to variety of metals and equipment but also as to the beauty of the exhibits, individually and collectively. Citations of individuals would be invidious — *all* excelled themselves. Whether it is the World's Fair influence, or whether it is a realization of the essential beauty of metal and its well-designed products, the result was a show of extraordinary appeal.

Nor will it be possible to give in brief space an account of the noteworthy things exhibited. The large October issue of METAL PROGRESS was none too big to sketch the recent progress of various branches of the metallurgical industry. The National Metals Exposition presented in concrete form the ideas portrayed but imperfectly in that publication.

Almost exactly one-quarter of the total membership of the American Society for Metals registered in attendance at the convention and attended the exhibits. About 1100 members of cooperating engineering societies also were registered. Entrance to the exhibit hall was denied to all except adults who registered their name and position at the door; thus it is known that over 18,000 responsible men in industry entered and studied the exhibits.

All members of the Society can measure the optimism prevalent by the words spoken by Secretary Eisenman, in the last paragraph of his annual report:

"With all of the Society activities showing an income of over $5,000 in excess of its expenses, with the October issue of METAL PROGRESS carrying the largest volume of advertising since it was established, with the membership of the Society approximately 1000 more than a year ago, with all advertising income 30% over the previous fiscal period, and with the National Metal Exposition the largest since 1929, showing a 45% increase over the amount of space sold last year, with an increased educational activity on the part of the chapters, and with the con-

Reading from left to right is T. N. Holden, secretary, New York Chapter; John Johnson, secretary, New Jersey Chapter; H. G. Keshian, trustee; J. S. Vanick, chairman, New York Chapter; G. B. Waterhouse, trustee-elect; W. W. Buffum, general manager, Chemical Foundation, Inc.; Robert Ridgway, past-president, American Society of Civil Engineers; E. C. Bain, trustee; R. H. Watson, vice-president, U. S. Steel Corp.; Emil Gathmann, treasurer; R. S. Archer, trustee; T. M. Girdler, chairman, Republic Steel Corp.

At the right half of the table sat W. H. Phillips, president; Albert Sauveur, first recipient of Albert Sauveur Achievement Medal; A. E. White, first president of the Society; W. B. Coleman, past president and trustee; John Chipman, recipient of Henry Marion Howe Medal; V. N. Krivobok, Campbell Memorial Lecturer; B. F. Shepherd, president-elect; J. A. Mathews, vice-president, Crucible Steel Co. of America; W. P. Woodside, trustee; Walter Mathesius, trustee-elect; P. L. Gerhardt, manager, Commerce Hall; W. H. Eisenman, secretary.

tinued growth of the services from the chapters and the national office, the members may look to the future with a degree of confidence that the present success of the Society will be maintained."

In his presidential report at the annual meeting, W. H. Phillips dwelt much upon the educational activities of the various chapters. Even in those centers where well-developed schools of metallurgy offer extension courses, either in day or night classes, there has been discovered a good demand for intensive courses of six or eight lectures. Of course, cooperation with educational institutions in the presentation of curricular studies has been the established practice of some chapters for many years, but the unusual success of the Cleveland Chapter in expanding its membership by means of supplementary courses has encouraged so many others to similar ventures that approximately half of the chapters are planning to hold some educational courses during the coming winter. (Since President Phillips prepared his report, the Tri-Cities Chapter — Moline, Davenport, Rock Island — has expanded its membership by this method by 135 persons in a month, undoubtedly a record!)

B. F. Shepherd, President-Elect
Manager Rock Drill Division, Ingersoll-Rand Co.
Photo by Blackstone Studios

Election of officers was made under the recently adopted amendments to the constitution. Each chapter selected one man as its potential representative on the nominating committee, which consisted as follows: Bradley Stoughton, chairman, R. M. Pease, A. T. Clarage, G. R. Brophy, G. A. Webb, J. B. Johnson, and F. P. Flagg. This committee selected the following candidates for the vacant offices indicated:

President, one year: B. F. Shepherd; Vice-president, one year: R. S. Archer; Secretary, two years: W. H. Eisenman; Director, two years: Walter Mathesius; Director, two years: G. B. Waterhouse.

These nominations were published, and as no additional nominations were received, the unanimous ballot of the Society was duly cast for these gentlemen, to

At Banquet: Officers of the Society and Honored Guests

assume office directly after the convention.

Various awards for merit were made at the annual banquet. The President's Bell was again put into the possession of the Cleveland Chapter as the one which, in the opinion of the president, has performed best from all standpoints during the past year.

The Henry Marion Howe Medal was awarded to John Chipman for his paper "Application of Thermodynamics to the Deoxidation of Liquid Steel," judged by a special committee to be the outstanding contribution to 1934 *Transactions*.

In announcing the Albert Sauveur Achievement Medal, President Phillips said: "We, as a society, are justly proud of our Campbell Memorial Lecturers and our Howe Medalists and the contributions which they have made to our metallurgical literature. We have felt, however, an outstanding achievement in the field of metallurgy should receive a special recognition.

Therefore the Board of Trustees has created a new medal to be known as the Albert Sauveur Achievement Medal. This award is in the name of and in honor to one who has contributed so richly and inspired so universally workers of all classes in the field of metallurgy. It is highly appropriate, therefore, that the American Society for Metals should designate its Achievement Medal as the Albert Sauveur Achievement Medal in honor of one who is, beyond question, the peer of all metallographists."

A. E. White, first president of the Society, made the presentation, and Dr. Sauveur responded with some reminiscences of his attempts, no more than 40 years ago, to interest captains of industry in the microscopic study of steel, and expressed the hope that these same men could have attended the National Metal Exposition and be converted to the value of metallography.

An appreciation of Dr. Sauveur by H. M. Boylston, his student and his associate for years (until assuming the chair of metallurgy at Case School of Applied Science), appears on page 41.

G. B. Waterhouse, Trustee-Elect
Professor of Metallurgy
Massachusetts Institute of Technology

Walter Mathesius, Trustee-Elect
Assistant General Superintendent
South Works, Illinois Steel Co.

T. M. Girdler, president and chairman of the board, Republic Steel Corp., was the after-dinner speaker. His prepared address recounted his many reasons for being optimistic as to the future prosperity of the American steel industry. Many of these grounds for hope rest on advances in the art and science of metallurgy, and the widespread demand from the intelligent consumer for special products for special duties. (Departing from his prepared address, he paid a handsome tribute to American Society for Metals for its leading part in disseminating this information and raising the standards of performance in the plants not only of steel producers but of their customers.)

"Steel is no longer a standardized commodity, like sugar or wheat or coal," said Mr. Girdler. "We have entered into the age of specialized steels. In the future all steel is going to be manufactured to order, to fit the particular job to which it is designed."

He cited the automotive and aircraft industry, refrigerators, air conditioning, machine tools, as trends in this direction already in evidence, and the steel house and railroad transportation as fields over-ripe for exploitation. Going on, he very temperately and sanely discussed the economic and governmental conditions which are now hindering the rapid realization of these potentialities. Mr. Girdler's remarks on this subject have been so widely printed and commented upon by the daily press and weekly journals of national distribution, that it is unnecessary for them to be repeated here. The net impression he left on his hearers was one of great hopefulness that the period of trial-and-error experimentation is rapidly coming to a close, and out of it will emerge a long period of increasing industrial activity and improved economic conditions for all Americans.

Technical Sessions

As we have become accustomed to expect, the technical program (in charge of R. T. Bayless, assistant secretary) was packed with informative and suggestive papers. Sessions were devoted to problems of heat treatment, to radiographic inspection, to the aging of metals, to steel making and a whole day to grain size. Three sessions were also required to present the results of important researches into theoretical metallurgy and miscellaneous industrial problems concerning metals.

V. N. Krivobok, Campbell Memorial Lecturer

All these papers will in due time be published, with discussion, in *Transactions*. In this issue space is only available on pages 35 to 39 for notes on four of the dozen papers about grain size. The complete text will occupy all of the next quarterly issue of *Transactions* and should be in members' hands about the middle of December.

Dr. Krivobok, in his presentation of the Campbell Memorial Lecture, matched the excellence of former lecturers. No higher praise can be given. His interesting discoveries about the strengthening and toughening effect of high nitrogen in carbon-free chromium-iron alloys are published on the following pages.

An innovation in the form of an educational series of five lectures, one each afternoon, was an added attraction for those who put emphasis on the strictly practical aspect of every-day life. J. P. Gill, chief metallurgist, Vanadium-Alloys Steel Co., delivered this course, which was so well attended that one can predict that future conventions will contain similar features. While Mr. Gill's entire remarks fill a sizable book (already available for sale to absentees), some notes on the first phase of his subject are carried on pages 42 to 46. *(Continued on page 56)*

Nitrogen Improves iron-chromium alloys

The ninth Campbell Memorial Lecture described experiments to discover the cause of brittleness in the 18% chromium-iron alloys. Even specially made alloys of highest purity had low impact values, and so the problem was unsolved. But like many investigations, it developed important facts not in the direct line of research — in this case the discovery that nitrogen in these alloys acts like carbon in plain steels, and that annealed iron-chromium-nitrogen alloys, free of carbon, are very tough.

IN the Campbell Memorial Lecture, Dr. Krivobok described work done by him to discover the cause of the impact brittleness of 18% chromium-iron alloys. The most accurate chromium-iron equilibrium diagrams available show a "gamma loop" extending out from pure iron as far as the 15% chromium alloy. From 15% to 38% chromium the accepted diagram calls for an uninterrupted series of solid solutions; then an intermetallic compound, FeCr, is thought to put in its appearance.

Now if the alloys between 15 and 38% chromium be solid solutions, the physical properties should vary with changes in composition in a continuous manner. Yet suddenly, at about 18% chromium, the alloys become very brittle, as measured by impact tests. In order to discover whether this is due to the other elements incidental in steel, a series of alloys were made by his associate R. A. Lincoln of hydrogen-purified iron and electrolytic chromium; the alloys were melted in vacuo to avoid pick-up of atmospheric gases, forged to bars in order to refine the coarse ingot crystals, and "homogenized" by heating in argon at 2300° F. for 20 hr. to permit diffusion or phase change to proceed toward completion. All these alloys contained less than 0.01% carbon; they analyzed 0.001 to 0.016% nitrogen and were free of hydrogen, oxygen, and the other usual elements in steel.

Three parallel series of commercial alloys ranging from 14 to 20% chromium and with carbon at 0.02%, 0.10%, and 0.20% were also available to compare with these "pure" alloys.

It was observed that all four series of alloys lost toughness in a short range, starting at about 15% and ending at about 19%. There is small change in hardness or the tensile properties in this range. Neither could the phenomenon be related to grain size.

Dilatometric studies showed that the pure homogenized alloys below 17½% chromium did contract slightly on holding at 1825° F., which "should be accepted as a well-founded indication of phase change, affecting, in all probability, but a very small portion of the sample. In other words, the gamma-plus-alpha region in the equilibrium diagram (the end of the gamma loop) extends to higher concentrations of chromium than is generally mentioned" — quotations are his.

Direct quotations are
by Vsevolod N. Krivobok
Professor of Metallurgy
Carnegie Institute of Technology

However, this did not explain why a continuous series of true solid solutions — that is, a single phase alloy — should have uniformly good tensile properties but sometimes good and sometimes poor impact values. An extensive series of experiments was then made on the age hardening of the pure and the commercial alloys. Samples were cooled from 1450 and 1950° F. and aged at 875° F. It was proved that "carbonless alloys show a most pronounced and definite tendency to age harden, and to a degree directly proportional to chromium concentration, within the limits studied. For instance, the total increase in hardness for an alloy with 18.2% chromium was, at the end of 425 hr., 26 points on the Rockwell B scale."

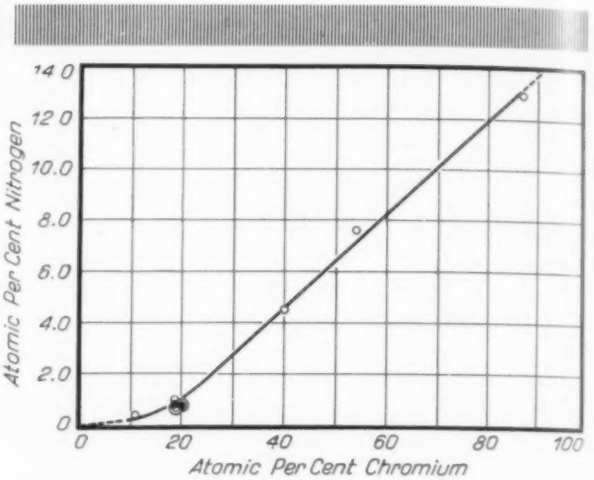
X-ray and microscopic studies failed to reveal any new constituent in the microstructure of the aged samples. "Of course this is not altogether surprising, for the aging phenomenon is not necessarily caused or accompanied by precipitation in the ordinary sense — a well-known example being duralumin. But aging experiments provide further illustration of the changes that take place in the supposedly one-phase (solid solution) region."

Similarity to Refrigerated Iron

Next, the lecturer described investigations of the supposed analogy with the low-temperature brittleness of common iron and steel. While this is an unexplained fact, it is known to be independent of any phase change, because iron regains its toughness after warming.

"Ductility in tension (elongation and reduction of area) is not adversely affected by refrigeration to —100° F. But ductility as measured by impact varies within wide limits regardless, it seems, of carbon content and of previous heat treatment. More specifically: At —100° F. all of the alloys are exceedingly brittle. At room temperature sharp demarcation between ductility and brittleness in carbonless alloys occurs somewhere between 16.75 and 18% chromium. At 122° F. alloys containing carbon and a carbonless alloy with 33% chromium are hopelessly brittle. Thus, the higher the chromium the higher is the temperature at which ductility is regained.

"These observations, it will be agreed, parallel those on iron." However, they offered no solution to the main problem of low impact, starting in at 17% chromium, other than to show that large changes in impact brittleness can occur without phase change in the alloy.



When Iron and Chromium Are Melted in the Presence of Excess Nitrogen the Resulting Alloy Contains an Amount of Nitrogen Depending Upon the Chromium Content

Finally, attention was directed toward impurities in the alloys. Total impurities in the specially prepared alloys were so low that Dr. Krivobok determined to study this problem by adding impurities to other melts, and studying the effects. Nitrogen seemed to be the likeliest element, for little is known about its action in chromium alloys other than that it alloys with chromium (if not with iron) very readily, "with the strong probability that a nitride is formed." Some alloys were prepared by melting purified iron and chromium under nitrogen, and by melting purified iron and nitrogenized ferrochromium. Carbon was kept very low (below 0.014 in most alloys); the analysis of the alloys is plotted in the first figure, above.

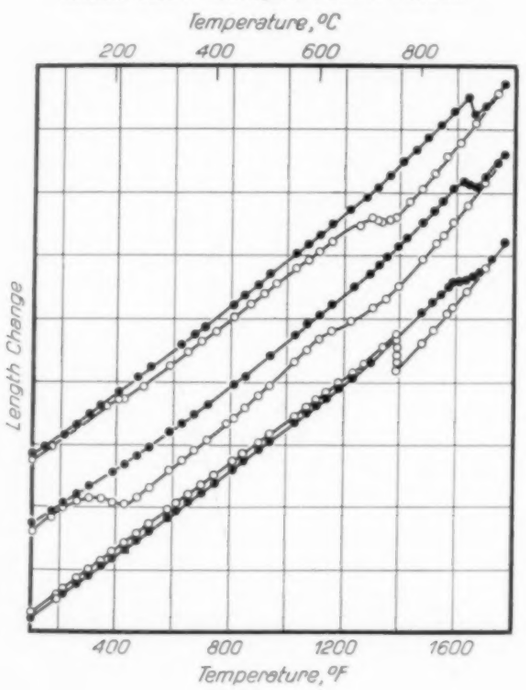
"It becomes evident at first glance that the amount of nitrogen absorbed during remelting is directly proportional to the chromium concentration, except for a slight deviation from the straight line when chromium is less than 10%.

"Regardless of the initial composition of the charge the final nitrogen percentage was the same, obviously determined by the chromium in the alloys: It may be arbitrarily called 'maximum allowed.' By changing the composition of the gaseous mixture it is possible to control nitrogen concentration, that is, to introduce less nitrogen, but to increase the concentration above the maximum was found impossible.

"Realizing this unusual affinity of iron-chromium alloys for nitrogen, it appeared indeed desirable and important to ascertain the influence of nitrogen on the constitution and properties of the chromium alloys.

"Dilatometric observations immediately disclosed a very pronounced influence of nitrogen on the phase relationships in nitrogen-bearing alloys. It will be remembered that alloys of 18% chromium are characterized by continuous, smooth, 'length-temperature' curves. The typical curve for the similar alloy but with nitrogen proves the existence of a definite, sharply defined transformation, both on heating and cooling. (Observe the diagram printed just below.) With

Iron-Chromium-Nitrogen Alloys Contract, on Heating, at About 1625° F., With Formation of a Gamma Phase and Reverse the Transformation at Temperatures Depending on the Rate of Cooling — an Action Quite Similar to That of Carbon Steel. Sample tested analyzed 18.06% chromium, 0.21% nitrogen, 0.009% carbon



smaller percentages of nitrogen the magnitude of the transformation diminishes, but the temperature range remains apparently unaffected. In other words, addition of nitrogen results in the formation, under equilibrium conditions, of increased amounts of the gamma phase, very much like carbon. Similarly with carbon alloys, the transformation in nitrogen-containing alloys can be made to occur at any temperature between 400 and 1475° F., depending on the rate of cooling. And, as should be expected, the common mechanical properties of the alloys undergo radical changes when subjected to heat treatment.

"As an example, the ability of the metal to harden is illustrated in the following figures for the same alloy containing 18.06% Cr, 0.21% N:

Quenching Temperature	Rockwell Hardness
675° F.	C-32
1000	C-29
1200	C-8
1400	C-3
1600	C-5
1700	C-28
1800	C-36
1900	C-40
2100	C-27

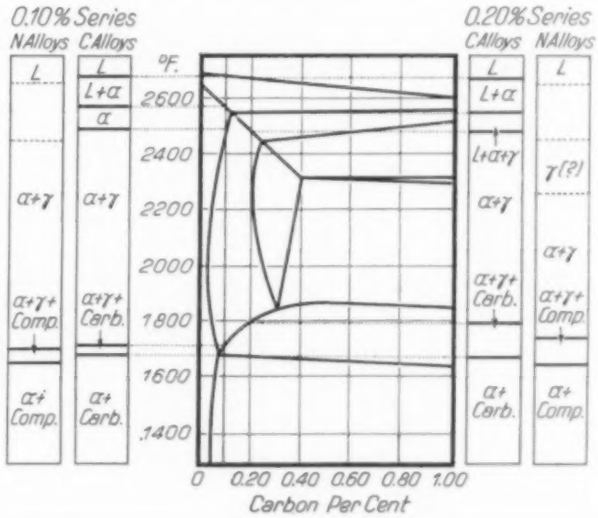
It was observed that the hardening power of nitrogen exceeds that of carbon.

"By controlling the nitrogen content and with proper heat treatment, impact characteristics far above those obtainable in alloys without nitrogen can be easily secured. For instance, an alloy containing 18.26% chromium, 0.125% nitrogen, and 0.006% carbon had a toughness (as measured by modified Charpy impact) of 120 ft-lb. when normalized from 1650° F. Corresponding figures were 113 ft-lb. after quenching in oil and drawing at 1400° F., and 83 ft-lb. after annealing at 1400° F.

"Microscopic study of the alloys (given in part at the foot of these pages) shows that the alloys of iron, chromium and nitrogen appear to be built up of the following:

"*Equilibrium Phases:* (*a*) Ferrite — a solid solution of iron, chromium, and probably some nitrogen. (*b*) A compound the nature of which

Diagram Showing the Analogy Between the Structural Constituents Existing in Heat Treated 18% Chromium-Iron Alloys Containing 0.10 and 0.20% Carbon and Similar Amounts of Nitrogen



is as yet subject to speculation. (*c*) Austenite — at high temperatures the compound goes into solid solution with ferrite, forming austenite.

"*Structural Constituents:* (*a*) Martensite — a product of incomplete decomposition of austenite upon cooling; the word is used arbitrarily to denote the structural appearance of the constituent. (*b*) Pearlite — a eutectoid of ferrite and compound, formed from austenite upon exceedingly slow cooling.

"In an alloy containing 18.1% chromium, 0.21% nitrogen, and 0.009% carbon, homogenized for 12 hr. at 2250° F. and cooled in air, the relative amount of austenite in equilibrium with ferrite at the high temperature of treatment is almost predominating. Naturally, at the rate of cooling used, the austenite has not been retained as such. Its partial decomposition presents typical martensitic appearance, as shown in the first micro. Heating this alloy at 1700° F. (in a region where three phases are in equilibrium) results in the separation and agglomeration of a compound which can be seen in the second micro.

"In this structural condition, alloys possess maximum softness and ductility. Deeper etching of the samples resulted in the pitting of ferrite, masking its appearance. It is probable that this 'pitting' is in reality etching around small particles of compound separated from ferrite.

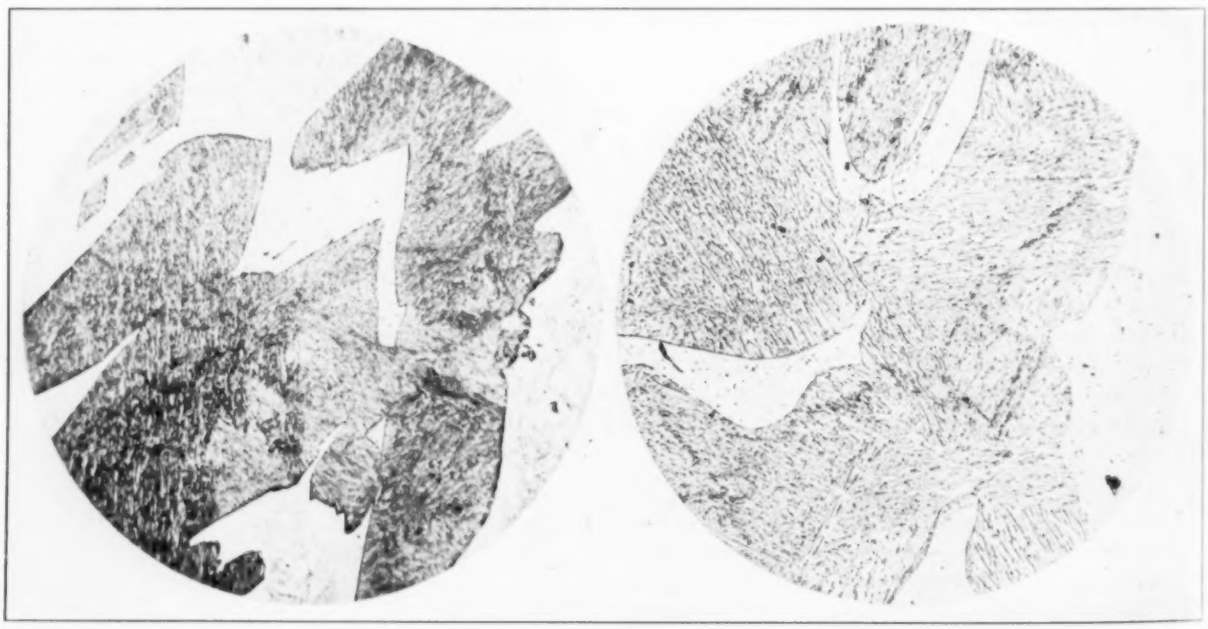
"At temperatures of 1800° F. and higher, the three-phase region is passed and alloys are composed of austenite and ferrite. The success in retaining austenite depends entirely on the rate of cooling, such as very rapid cooling in ice brine, whereupon the grains of austenite are dispersed through the matrix of ferrite. Less rapidly quenched, this alloy has typical martensite, predominating over ferrite because of its high concentration of nitrogen (near the 'maximum allowed') as shown in the third view.

"Upon increasing temperature the alloy appears to enter the field of a single gamma phase; at 2200° F. and above, only very small and isolated ferritic grains could be found — which may not be a true equilibrium phase.

"When separation of the compound takes place at temperatures below the three-phase region it sometimes takes on a peculiar form of platelets, somewhat resembling well-known nitrogen needles (the fourth photograph); the dark appearance of these plates is due to staining.

"It also appears that the compound is quite brittle, from its shattered appearance at high magnification.

18% Chromium, 0.21% Nitrogen, 0.009% Carbon Alloy Is a Mixture of Austenite and Ferrite. The austenite, on slow cooling, partially transforms into the darker etching constituent, as shown at left, magnified 200 diameters, which can be converted into definite martensitic or pearlitic structure by appropriate heat treatment. After long soak at 1700° F. a compound has separated from the austenitic grains, appearing as the long stringers in the darker areas of the right micro at 500 diameters, a compound now of unknown composition



"The same structural constituents were also found in alloys of other composition, the amounts of various phases being of course dependent upon analysis. Alloys of lower chromium, 10% or less, were observed to have markedly lower resistance to corrosion. Even upon etching with dilute acids the ferrite constituent is deeply stained.

"While this information is not sufficient for a structural diagram of the iron-chromium-nitrogen system, the powerful influence of nitrogen on practically carbonless alloys can be represented approximately as in the diagram at the foot of page 23.

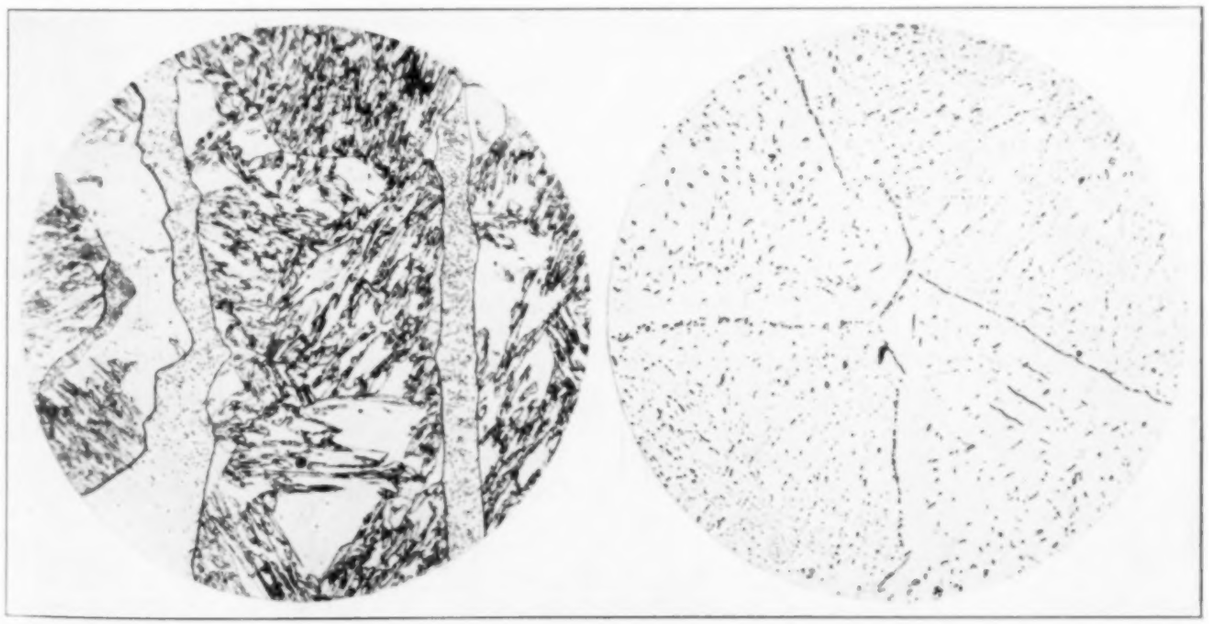
"For its construction, alloys of the same chromium percentage were selected — namely 18% — but containing either carbon or nitrogen, in *equal* amounts. Vertical isotherms corresponding to a given carbon concentration, were drawn on the equilibrium diagram until they intersect the limits of various fields and are then projected on the column to the right of the diagram; the regions occupied by various phases and their temperature limits become clearly represented. Side by side is shown an analogous representation of experimental data for nitrogen-bearing alloys. Of course, these simplified graphs do not convey the idea of the relative amounts of different phases. From the examination of numerous structures and heat treatment data, it would appear that the eutectoid composition corresponds to much lower values of nitrogen than of carbon. In fact, it is quite definitely reflected in some of the mechanical properties of the alloys.

"The discussion of nitrogen in iron-chromium alloys was deliberately confined to alloys with very little or no carbon. What influence nitrogen may have on chromium irons and chromium steels can, at the present, only be speculated upon. For this reason it had better be left undiscussed."

* * *

Dr. Krivobok closed his lecture with acknowledgments to various collaborators in these studies, and without attempting to give an answer to his original query — "Why are 18% chromium alloys brittle?" Perhaps the question is answered, as far as it can be at present, by the observation that they are not necessarily brittle, for if the alloy contains considerable nitrogen and is heat treated so the nitrogen constituent develops a pearlitic microstructure, the alloy is as tough as you could well wish.

At Left Is the Same Alloy Quenched After Holding at 1800° F. for 3 Hr. Showing That the Nitrogen-Austenite Has Transformed Into Typical Martensite. If excess constituent is precipitated at temperatures where alpha iron is theoretically stable (1700° F.) it sometimes appears as platelets, resembling "nitride needles" in arc welds when made with bare electrodes. Both these views are magnified 500 diameters



Brass Die Castings as well as others

A feature of the interesting program arranged by the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers for the National Metal Congress in New York was a day devoted to the die casting of aluminum, copper, and zinc base alloys, and die steels. At the Division's annual dinner Sam Tour also spoke informally on the influence which the perfection of the die casting art has had on other related industries.

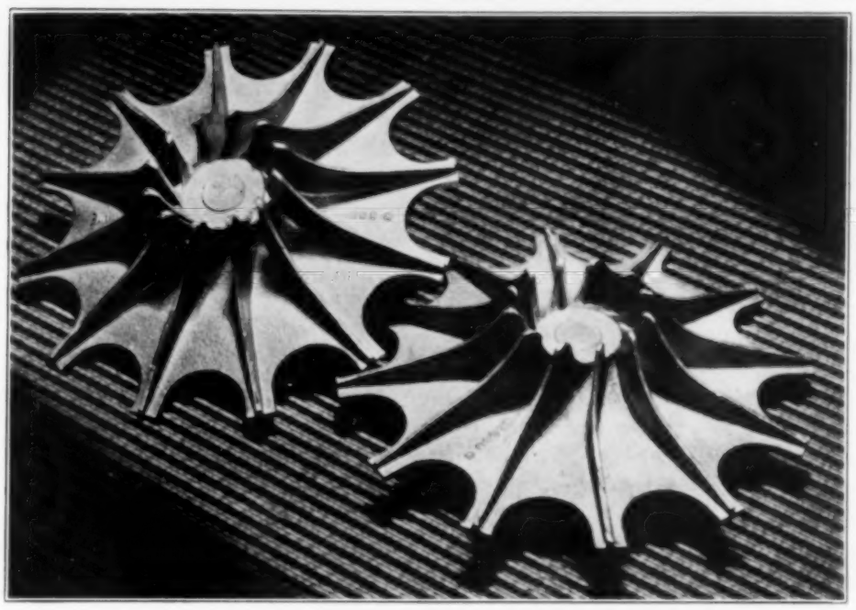
CASTING of metal in open metal molds is an ancient art whose origin is lost in antiquity; very old examples are the casting of lead alloys into bullets and printing type. It is worthy of mention that die casting, as we know it today, was first commercialized about 70 years ago by Mergenthaler's linotype, where a slug of lead alloy was cast *under pressure* against brass matrixes.

Tin alloys and zinc alloys are also easy to cast in steel dies, but aluminum alloys with higher melting points cause trouble, not only from thermal stresses in the dies but also from attacking the melting pots and gates. Such troubles have been endured, but were too much where brasses and cast irons were concerned. Permanent mold castings have been made in quantity of both metals last mentioned, true enough, but the plan of forcing liquid metal into a cavity by pressure (typical of true die casting) has been replaced by the old, old process of pouring open molds by gravity, or by the use of centrifugal force or suction; even when casting at a slow rate the problem of die steels is acute.

Hence the most interest during a day devoted to problems of the die casting industry was shown in an account of progress made by the American Brass Co. by its metallurgist John R. Freeman, Jr. The general problem of die casting in brass and its solution was discussed by Charles Pack in METAL PROGRESS in July, 1931.

The casting is usually of a Muntz metal (60:40 brass), and a small ladle-full of metal just above its melting point is dipped out and swirled about until it becomes a mushy ball. It is then dropped into the cylinder of the Polak machine and forced into the die through a center gate by pressure from two opposing plungers; the upper one closes the opening through which the ball was introduced. Excess of metal is sheared off and ejected by an upward motion of the lower plunger. At the start the metal is as cool as possible in order to protect the dies and plunger from heat, and also to prevent liquid from forming a fin of metal which is likely to wedge between plunger and cylinder wall.

In the Pack machine the metal is ladled into a cylindrical receiving chamber at a somewhat higher temperature and remains quiet long enough for a shell to chill around the walls. Then the chamber is locked by an upper slab which contains the gate, and the bottom of the chamber (which is a plunger) rises, forcing the metal into the die. The chilled skull effectively prevents squirting back through the clearance



Rotors for Super-Chargers, Die Castings by Bohn Aluminum and Brass Corp.

between chamber walls and plunger, and extra metal is lifted out with the casting and gate.

Mr. Freeman emphasized the fact that the American Brass Co. has machines of both types in successful operation. The Muntz metal, although a low melting brass, has its narrow mushy range widened by adding at least 0.5% lead. Lead also increases the machinability. 0.1 to 0.2% aluminum prevents undue scum (oxidation) during manipulation, reduces evolution of zinc in the melting pot, and hinders a deposit of zinc oxide on die surfaces. Tin (in quantities to 1%) opposes the segregation of lead in the mushy state and increases corrosion resistance.

A suitable composition therefore is 60% copper, 1% tin, 1% lead, 0.10% aluminum, and balance zinc. In the form of die cast 0.505-in. test bars its minimum tensile strength is 45,000 psi., elongation 9% in 2 in., and Charpy impact 13 kg-m. per sq.cm. A patented silicon bronze known as Webert alloy is also suitable for die casting. Its nominal composition is 81.5% copper, 4.25% silicon, 0.15% manganese, remainder zinc; it melts at about 1650° F. Its minimum properties are 85,000 psi. tensile strength and 8% elongation in 2 in. In smaller sections the chill effect shows in a 10% increase in the tensile strength of these brasses with no accompanying change in ductility.

(As noted in last month's issue, page 47, aluminum bronzes have been cast in permanent molds for several years by a method which sucks the metal by vacuum into a steel die through an opening immersed in the molten metal. This quiet flow deposits any of the troublesome aluminum oxide on the die surface rather than shooting it through the body of the casting. Such castings have been made up to 30 lb. in weight; tensile specimens cut from them will range up to 80,000 psi. tensile strength and 260 Brinell, depending on heat treatment.)

Mr. Freeman also discussed the relation of composition to physical properties — a matter considered at some length in a second paper by O. B. Malin and W. W. Sieg who believe that about 0.5% silicon and 0.2% iron will improve the hardness and strength of Muntz metal containing lead without making the castings liable to porosity. Experience shows that the preferred analyses quoted by both authors will produce castings with no visible cavities if the temperature and pressure are right. Under the microscope there are a few cracks to be found, and hence the articles are not as good as forgings, especially for high pressures.

As to utility, the brass die castings seem to be midway between sand castings and forgings, and will probably find application where con-

siderable machine work or expensive assemblies can be eliminated by accurate dies and cores, and where superior strength is required.

Purer Aluminum Alloys

The matter of purity of metal in aluminum die castings has also been under investigation, especially as regards the corrodibility of the commonly-used alloys with nominal 5% and 12% silicon. E. H. Dix, Jr. and J. J. Bowman of Aluminum Research Laboratories exposed a series of die cast plates to salt spray tests; in these castings the usual impurities were under control and progressively restricted to very small amounts. Copper appeared to be an accelerator of corrosion; tin was also deleterious in the 12% silicon alloy, whereas iron, manganese, nickel, and magnesium were indifferent.

Messrs. Dix and Bowman reported to this meeting experiments on 12% silicon alloys of high purity; also similar ones containing considerable iron and nickel. These are substantially unaffected in salt spray after 26 weeks — that is, there is less than 10% change in tensile properties, of which some may be due to the aging effect — and are definitely superior to 12% silicon castings that meet the A.S.T.M. specifications as to chemical analysis. Growth is on the order of the change in dimension due to temperature rise of 4° F.

It will be recalled that the A.S.T.M. committee on aluminum die castings has embarked on a test program to determine the relative properties of the 5% and 12% silicon alloys of ordinary and extra high purity when made in a commercial way. Standard round and flat test pieces have been made by two firms, and will be tested for mechanical properties after outdoor exposure for various times and in several atmospheres, and also after salt spray accelerated corrosion up to one year. The analyses of these die castings are as follows, where the first figure represents the bars of ordinary quality and the second figure represents the values for the test bars of extra high purity: Iron 1.38 and 1.14%; copper 0.42 and 0.09%; manganese 0.22 and 0.01%; magnesium 0.05 and 0.01%; zinc 0.52 and 0.00%; nickel 0.32 and 0.01%; tin 0.05 and 0.00%; lead 0.03 and 0.00%. (Iron, of course, is picked up from the melting pots.)

A Man Who Knows His Magazines as Well as His Metals Is E. H. Dix, Jr., Chief Metallurgist of Aluminum Research Laboratories, and Past Chairman of the Pittsburgh Chapter. His contributions to Transactions and METAL PROGRESS *have been notable and numerous*

Die Steels

Steels for dies give no trouble when casting zinc and lower melting alloys — plain carbon steel and nickel-chromium (S.A.E. 3150), used without heat treatment, last indefinitely. The hotter aluminum and magnesium require steels which have superior resistance to scour and to rapidly alternating thermal stresses; even then the loss from "heat checking" is an important item of cost. Actual temperatures attained while die casting aluminum at 1250° F. have been measured by R. G. Roshong of the Hoover Co., with delicate thermocouples imbedded near the surface, and found to be 475 to 500° F. Surface temperatures are doubtless considerably higher when die casting brass.

Sam Tour presented the result of some studies on a series of die steels made in cooperation with Mr. Roshong and J. P. Gill of Vanadium-Alloys Steel Co. Die steels contain 0.35 to 0.45% carbon; up to 1% silicon is added to decrease scale during heat treatment and to improve resistance to erosion by liquid metal. About 5% chromium and an equal amount of tungsten make such a steel air-hardening and maintain a good degree of hardness at operating

William B. Price, Chief Chemist and Metallurgist, Scovill Manufacturing Co., Is One of the American Pioneers in Brass Technology. He, W. R. Webster and the lamented W. H. Bassett, have been leaders in the Institute of Metals since its founding

temperatures. Dr. J. A. Mathews of Crucible Steel Co. thinks that if a considerable part or all of the tungsten is replaced by molybdenum the steel will retain its toughness after long stays up to 850° F. Either variety, when heat treated in 4-in. cubes, will air harden from 1900° F. to about 460 Brinell over the entire face; drawing at 1075° F. for 5 hr. will reduce this to 387. Mr. Tour also reported Charpy impact tests on key-hole notched bars at elevated temperatures, showing that these two steels had toughness unchanged, at 16 to 18 ft-lb., up to temperatures of 800° F. Original hardness of the impact specimens was Rockwell C-46. The molybdenum-containing steel is also ductile when as hard as Brinell 532; elongation in standard 0.505-in. test bars is 12% in 2 in.; reduction of area 42%. Warpage is low; values for the test specimen shown on page 45 of this issue are: Minor diameter +0.0011 in.; major diameter +0.0003 in.; slot —0.0067 in.

Die casters would be glad to find some preliminary test to indicate relative desirability of a steel short of actual trial; perhaps the best method now in vogue is to make gate bushings of it and measure their life. Mr. Tour believes that a steel should have low coefficient of expansion and high thermal conductivity, elastic limit, endurance limit and toughness (all at working temperatures). Mr. Roshong, however, cited an instance where steels with good toughness failed by heat checking in three weeks, whereas an insert of high carbon, high chromium steel, more brittle, lasted four years.

Cost and machinability also enter into the picture, especially for the custom shop. Great expense would be warranted for a die capable of 100,000 shots, but such a long run can seldom be guaranteed. The result is that 40¢ a lb. is around the top price for die steels for miscellaneous production. Furthermore, the tungsten die steels have about reached the limit of machinability, even when normalized and annealed to Brinell 225.

H. G. Keshian of Chase Brass and Copper Co. said that brass die casters had tried a number of different steels, and that those with higher alloy (say up to 7.5% of both tungsten and chromium) were performing fairly well. These are air hardening to a maximum of Rockwell C-55; they develop secondary hardness, and if the tungsten is much higher than the chromium, may be heat treated like high speed steel. They readily carburize, so that the packing material is important; a salt bath is good for small pieces, and large ones may be packed in pitch coke, which is rather more inert than cast iron chips at temperatures above 1600° F. They can also be nitrided easily, and this hardening treatment for dies is receiving attention.

Sam Tour, Vice-President, Lucius Pitkin, Inc., Testing and Consulting Engineers, Is Expert on the Manufacture of Die Castings, Having Been Metallurgist for Doehler Die Casting Co. for Many Years. Being past chairman of the New York Chapter was another reason for his activity at the recent Convention

New Pyrometer for very hot gases

Hot gas-air mixtures radiate so little visible light that their temperatures have heretofore been measured indirectly. Mr. Mattocks describes a successful device whereby a little salt is injected into the hot gas (2300 to 5000° F.) and the resulting yellow sodium line is viewed against the continuous spectrum from a calibrated incandescent tungsten band lamp.

IT is well known that thermo-electric pyrometers are limited by the temperature and atmosphere which cause the couple wires to deteriorate rapidly. Even the platinum couple cannot be used much above 2800° F. Beyond those temperatures three types of accurate measuring devices are available—(*a*) optical pyrometers, (*b*) radiation pyrometers, and (*c*) spectral-line reversal pyrometers. The limitations of these devices will now be briefly outlined, especially as they apply to the measurement of gas temperatures.

None of these devices require direct contact with the medium, but derive their motivating action from the energy radiated from it. In order to operate successfully, the radiant energy must generally be in the visible spectrum. (The total radiation pyrometer constitutes the one exception to this rule.) Therefore, either the gas must be luminous or light must come from a solid body surrounded by the gaseous medium—its temperature is assumed to be the same as that of the gas, and this assumption is seldom justified. In some special cases, radiation of a definite wave length is desired and may be secured by introducing some extra substance into the gas stream, such as ordinary table salt, when the prominent sodium yellow is obtained.

by E. O. Mattocks
Industrial Engineer
American Gas Association Testing Laboratory
Cleveland

Optical and Radiation Pyrometers

The most frequently employed device is the optical pyrometer. With it the intensity of the visible rays radiated from some object immersed in the hot gas is compared with rays from a known source. The most common optical pyrometer is the disappearing filament type, in which the brightness of a tungsten filament inside a special lamp is regulated so that the image of a specified portion of that filament is made to just disappear on the background of light from the object whose temperature is being obtained.

In order to secure a good comparison of light intensities from lamp and object, filters are usually employed so that the red rays predominate. The use of filters also allows a lower filament temperature in the comparison lamp, and a consequent increased life of that part. The amount of current necessary to raise the temperature of the filament so that a perfect match can be obtained is ordinarily measured with a sensitive ammeter. From previous calibrations, the

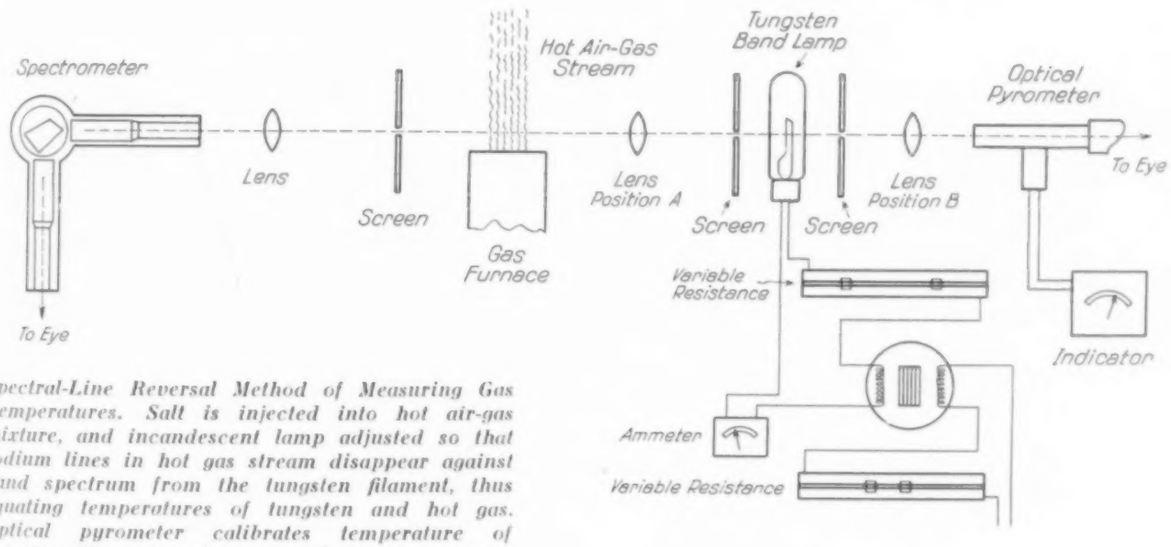
temperature corresponding to the observed amperage can be determined.

Optical pyrometers are useful in the range from 1400 to 5000° F. The most favorable atmosphere is absolutely clear — free of incandescent particles of dust or carbon. The major precautions to insure correct readings are to correct the radiation from the object observed to "black body" conditions, and to clear the atmosphere between object and pyrometer so absorption of radiant light will be cut to a minimum. The above assumes that every effort has been made to insure that the radiating body is at the same temperature as the gas. How difficult this is has been briefly pointed out in a former article on thermoelectric pyrometers by the present writer in July's METAL PROGRESS.

So much for the conventional optical pyrometer. If the total frequency range of radiation from the heated object, instead of just the red rays in the visible spectrum, is passed through a collimating tube and focused onto a thermocouple junction, the temperature of the object can be inferred from the amount of electric energy generated in the thermocouple. Such a device is called a radiation pyrometer. Since an electric current is produced by the instrument, readings can be recorded continuously on an automatic recorder which in turn can be used to control, automatically, the quantity of heat to the process, using standard equipment for this purpose.

This type of device has the disadvantage that it yields black-body temperatures, but so long as the object viewed is encased within a furnace chamber, errors of this kind are minute. Furthermore, the gases between the object and the temperature measuring instrument absorb a certain amount of the radiated energy and are thus responsible for low readings. For similar reasons, care must be taken to keep dust from collecting on the focusing elements of optical and radiation pyrometers, since a slight accumulation will absorb or diffuse an appreciable amount of energy and therefore introduce a considerable error.

Radiation pyrometers have the same useful range as optical pyrometers and the same precautions must be taken to insure accuracy. Since a thermocouple is an essential part of such devices, additional corrections must be made for the cold junction temperature, and for any deviation greater than 1% from the standard curve of millivolts vs. temperature.



Spectral-Line Reversal Method of Measuring Gas Temperatures. Salt is injected into hot air-gas mixture, and incandescent lamp adjusted so that sodium lines in hot gas stream disappear against band spectrum from the tungsten filament, thus equating temperatures of tungsten and hot gas. Optical pyrometer calibrates temperature of tungsten filament against current passing to lamp

Spectral-Line Apparatus

As a final consideration in this paper, let it be supposed that it is required to obtain a *gas* temperature above the useful range of all commonly available thermocouples. If optical or radiation pyrometers are used, only a relative temperature can be had, representing the temperature of the solid object viewed and not the temperature of the gas surrounding it. Although they may be satisfactory for the purposes

of the process, readings thus obtained may not be considered true gas temperatures.

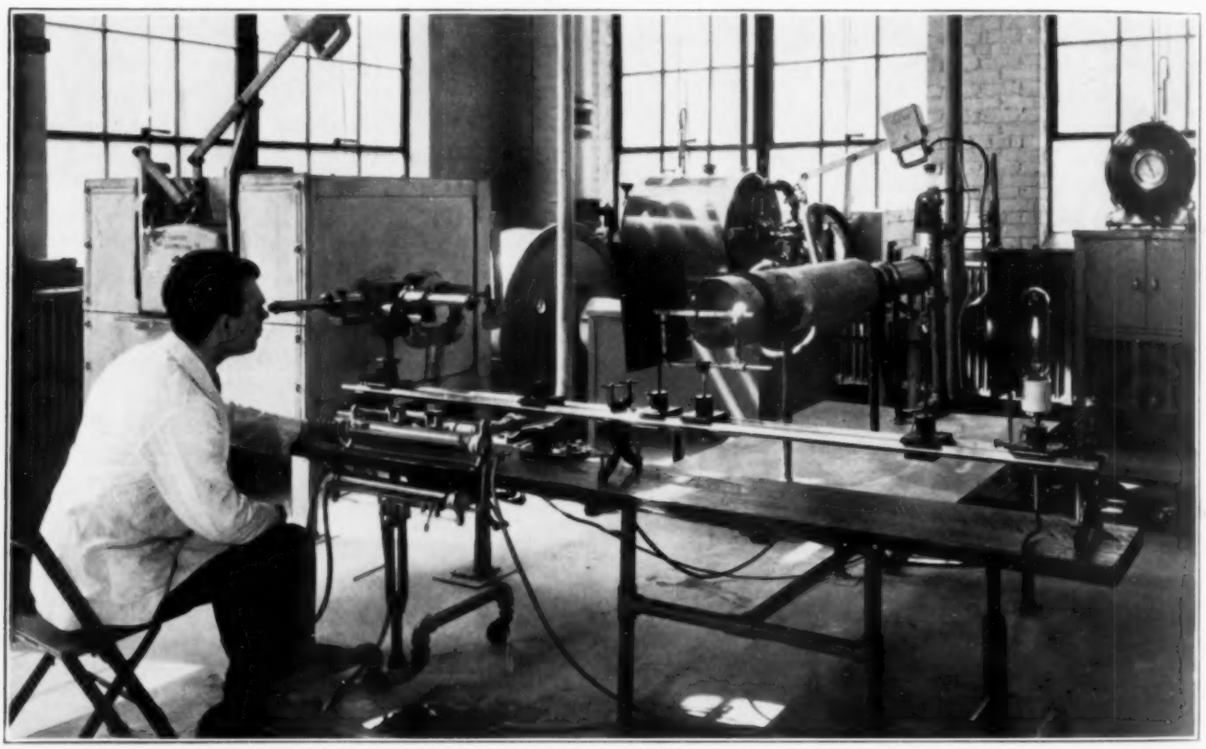
To ascertain high gas temperatures, it may be necessary to employ the spectral-line reversal method. This means of measuring true gas temperatures has been employed for several years for flame studies, but its adaptation to the accurate determination of incandescent gas temperatures is new.

To obtain a temperature measurement by this method, one compares some radiation of a certain wave length emitted from the gas stream whose temperature is desired, with radiation of the same wave length in a band spectrum obtained from either a carbon arc or the filament of an electric lamp. Since the latter is easier to manipulate, it is more often used.

The sketch on page 31 shows the general setup of the spectral-line reversal equipment used at the American Gas Association Laboratory and developed by the United States Bureau of Mines. The radiated energy from the filament in the tungsten band lamp is directed through the center of the hot gas stream and focused into a spectroscope, through which it is viewed as a band spectrum. In order to secure the additional radiation of a definite wave-length from the hot gas stream, some extraneous material may be injected into the gas prior to combustion. Generally, finely ground, ordinary table salt (NaCl) is used which produces the two familiar bright sodium lines, D_1 and D_2. These lines, as seen through the spectroscope, are superimposed on the band spectrum from the lamp.

If the lamp filament is cooler than the gas, the line spectrum of sodium will appear brighter than the background; if the filament is hotter than the gas, the lines will appear darker than the adjoining spectrum. By adjusting the current to the lamp (which changes the temperature of the lamp filament) a point can be reached at which the line spectrum just disappears into the band spectrum and becomes indistinguishable. At this point the temperature of the filament is the same as that of the gas.

Although a number of different salts may be used to produce the line spectrum to match with the band spectrum, sodium chloride is prob-



The Author, Using Spectral-Line Reversal Apparatus. Current through lamp at right end of bench is varied by the observer, and the ammeter read when the sodium line, as seen through spectroscope, vanishes. Temperature of lamp filament is then known from previous calibration and equals temperature of hot gas

ably best because of the brightness of the sodium lines and the cheapness of the material. It has, however, one major disadvantage. If the temperature is below approximately 2400° F., the sodium will oxidize if oxygen is present, thus destroying the line spectrum.

The maximum temperature for which the spectral-line reversal method can be employed is governed by the source of light giving rise to the band spectrum. If a tungsten band lamp is used, the point at which tungsten begins to become unstable is the upper limit. During tests conducted at the American Gas Association laboratory, under the supervision of the Committee on Industrial Gas Research, gas temperatures well over 3500° F. have been easily and successfully measured.

Limits and Precautions

Without going into the somewhat complicated theory it can be stated that if the temperature differences within the gas stream are not large, the measured temperature is close to the maximum and not the average within the gas stream. Therefore, care must be exercised to make sure that the temperature differential within the stream is not very large. It is possible, however, to obtain the temperature at any one specific position of the hot gas stream rather accurately by taking the proper precautions for preventing the radiant energy from the band lamp from passing through the gas stream at any point other than that being studied.

Probably the useful limits of the spectral-line reversal pyrometer are the range 2300 to 5000° F. *Any* atmosphere or flame can be measured, irrespective of its luminosity. Corrections to be made (other than those for the optical pyrometer used for calibrating the lamp) are for lens, color and water vapor.

The first correction is for the amount of radiant energy absorbed by the lens located between the band lamp and the hot gas stream (position A on the diagram). This source of error is eliminated by placing the same lens between the optical pyrometer and the band lamp (as in position B in the diagram, page 31) when calibrating the latter.

Since the band lamp is calibrated with red light, a color correction is necessary to obtain the true temperature of the yellow-colored gases. By using the values in Wien's equation for spectral emissivity which have been determined by W. A. Forsythe and A. S. Worthing for tungsten lamps, the magnitude of this error may be ascertained.

If sodium hydrate or a salt solution is injected into the air-gas mixture stream as a vapor, a correction is necessary to allow for the effect of water vapor on the gas temperature. Inasmuch as the determination of this error is very difficult, it was eliminated during our experimental work by employing pulverized dry salt.

By applying these necessary corrections, high gas temperatures can be obtained by this method that are within ± 10° F. of the true gas temperature.

In summarizing the above, it must be remembered that the conventional optical and radiation pyrometers measure the temperature of solids and do not measure true temperatures of the gases enveloping them. The method described herein (the spectral-line reversal method, injecting some substance into the gas stream in order to secure monochromatic radiation), although not applicable to all needs, offers a reliable means for securing the true gas temperature above the range in which ordinary thermocouples may be employed. For lower temperatures the precautions given in the writer's article on thermoelectric pyrometers, in METAL PROGRESS for July, should be observed.

Snapped at the National Metals Exposition Was John A. Malone, Industrial Engineer, Consolidated Gas Co., New York, and Chairman of the Exhibit Committee of American Gas Association, a Prominent Factor in the Success of This and Past Expositions

Grain Size of Steel

discussed at convention

Twelve papers were presented before the A.S.M. Convention discussing various aspects of grain size, such as its control during steel manufacture, its effect on the properties and uses of various steels such as screw stock, deep drawing and magnetic sheet, S.A.E. steels and tool steels, and the fundamental reasons for a difference in grain size of steels of similar chemical analysis after comparable heat treatment.

THE two sessions on the last day of the American Society for Metals Convention were devoted to grain size and were notable for a description by steel company metallurgists as to how grain size is controlled in open-hearth practice. It has been generally held that the essential difference between fine grained and coarse grained steels, as determined by the McQuaid-Ehn carburizing test (and that will hereafter be the significance of the unqualified word "grain"), is that the former contains a cloud of submicroscopic refractory particles, which either form nuclei for fine crystallization, or obstruct natural grain growth. It was also known that strong deoxidizers like aluminum, titanium, zirconium, and vanadium, when added to molten steel, caused fine grain in the heat treated product. Nevertheless, actual furnace practice to secure a fine grained product has seldom been talked about in public.

At this meeting, however, Messrs. Epstein, Nead, and Washburn gave data on a large number of open-hearth heats made by Inland Steel Co. showing that normal plant practice which produces good forging steel need not be readjusted except to control the final aluminum additions in order that the product may be either fine grained (grain size 5 to 7) or coarse grained (No. 2 to 3). The problem of regular production of intermediate grain sizes has not yet been solved.

Assuming the production in the furnace of properly deoxidized steel, containing 0.15 to 0.50% carbon, about 0.50% manganese, and not much less than 0.15% silicon, fine grain can be insured by adding 1 lb. aluminum per ton of steel in the ladle. If manganese is higher, silicon may be lower — under favorable furnace conditions it may be as low as 0.07%.

Aluminum additions to the mold are more effective, and will give fine grain to steels even lower in manganese and silicon, but the practice of mold additions is usually regarded as undesirable. Some think that aluminum introduces dangerous inclusions into the steel; on the other hand, aluminum has definite advantages in steel making as a deoxidizer, and may be added in the ladle to steels of 0.10% silicon content in quantities up to 0.5 lb. per ton if a coarse grained steel is desired. Fine grain cannot be obtained by even a high silicon or manganese content in the absence of aluminum.

Grain size is therefore controlled by first making a good steel in the furnace, and adding in the ladle an amount of aluminum adjusted to the carbon, manganese, and silicon in the analysis (which really gives an idea of the

H. W. McQuaid (With E. W. Ehn) Discovered the Desirability of Controlling Grain Size When Solving a War-Time Production Problem at the Timken Roller Bearing Co. McQuaid is now metallurgist for Republic Steel

oxygen remaining in the steel when it is tapped).

In the above researches a number of heats were split, consequently a good idea could be had of commercial metal differing only as to grain size. There is no difference in ferrite grain size in the as-rolled condition provided, of course, the temperature at the last pass is below the critical, as is usual; only after reheating somewhat above the critical temperature does the differentiation exist, and all physical tests were made on bars air cooled from about 1700° F. Normalized, fine grained steels have about 5000 psi. higher yield strength. Although impact tests did not show the large differences expected, they were about one-third higher in the finer grained steel, particularly after cold working 9%. Ductility in tension tests is also somewhat higher. Such data do not indicate that the aluminum addition has harmed the steel.

The authors believe that steel makers are justified in controlling grain size on steels ordered for definite purposes, primarily in order to promote uniformity in production, and secondarily to prevent mystifying troubles often blamed mistakenly on other harmless variations (such as spread in chemical analysis). They also believe that fine grained steels belong to the forging steel grade rather than the commercial grade, since they require hot-top molds to control the extra tendency to pipe, and hence should carry the price extra for forging quality.

This simple explanation — that aluminum reacting on iron oxide forms Al_2O_3 particles, nuclei for crystallization — was challenged by H. W. McQuaid with some facts from electric furnace practice. "Electric furnace heats with silicon 0.20% or more can be very easily made fine grained while other heats with low silicon and high FeO are relatively difficult to make fine grained. Electric furnace slags are usually very low in FeO with correspondingly low FeO in the steel. The addition of silicon and manganese before tapping should result in well-deoxidized electric furnace steel, yet unless the heat has been boiled down and the scrap selected, the well-killed electric heat will be fine grained with a relatively small addition of aluminum.

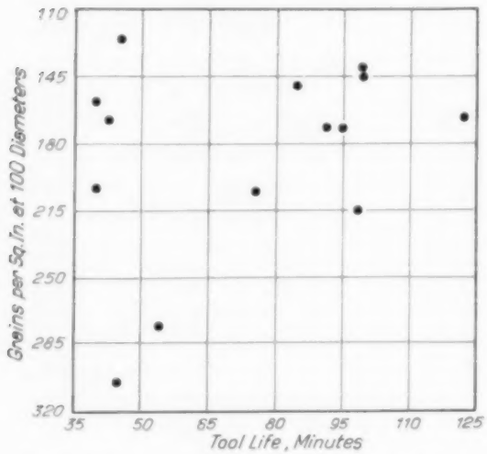
"The fact that variation in the deoxidation practice and aluminum addition affects the grain growth *range* as well as the grain size indicates that the cause of grain size is not nuclei, solid at molten steel temperature, but some compound of aluminum or vanadium which is present in the austenite grain boundaries and which changes its solubility at some definite temperature in the austenite. The effect of this solubility on carbon solubility would produce normality variation, and inhibit grain growth below a given temperature. This would account for the difference in grain size and grain growth between vanadium and aluminum killed steel and also the varying effect of different percentages of deoxidizer. Whether the compounds which produce the interference phenomenon are nitrides, carbides, or oxides, is a matter of speculation, but the indications are that the nitrides are a very important factor."

Grain Size and Machinability of Bessemer Screw Stock

One of the earliest discoveries about machinability of steels of forging grade was that coarse grain was favorable. H. W. McQuaid said that as early as 1919 the Timken Roller Bearing Co. demanded metal from its suppliers which had been rolled with maximum permissible temperature on the billet furnace and finished definitely above the temperature for a coarse grain in the as-rolled bar. Furthermore, the prime reason for normalizing forgings is to coarsen the grain and improve the machinability.

One class of material, namely bessemer

screw stock, represents the utmost in machinability, and a study of it by H. W. Graham of Jones & Laughlin Steel Corp. contains much of interest. Screw stock is usually delivered as cold drawn bars, and after this treatment is of such a nature that it ages at room temperature. An Izod test would then show low toughness. It is Mr. Graham's belief that the rapid loss of impact strength in slightly cold-worked bars upon aging is the best criterion of machinability in screw stock.



Tool Life (Running Dry) Plotted Against Grain Size of Bessemer Screw Stock From Various Sources in the As-Received Condition Shows Only a General Relationship. All material would be classed as grain size No. 8

Since this material is machined in condition as received, the grain size as received rather than the grain size after the McQuaid-Ehn test should be compared with machinability. Fourteen lots of steel from six different bessemer plants were investigated. As received they were all of grain size 8 by the A.S.T.M. chart, but there was still a considerable range in size — 126 to 307 grains per sq.in. at 100 diameters. Machinability was determined on an automatic lathe, by noting the tool life when running under standardized conditions without coolant. The diagram plots the results. "Although no line is drawn," said Mr. Graham, "it shows an improvement of machinability with an increase in grain size." (These materials are usually abnormal after the McQuaid-Ehn test, with coarse and fine grain in the same field.)

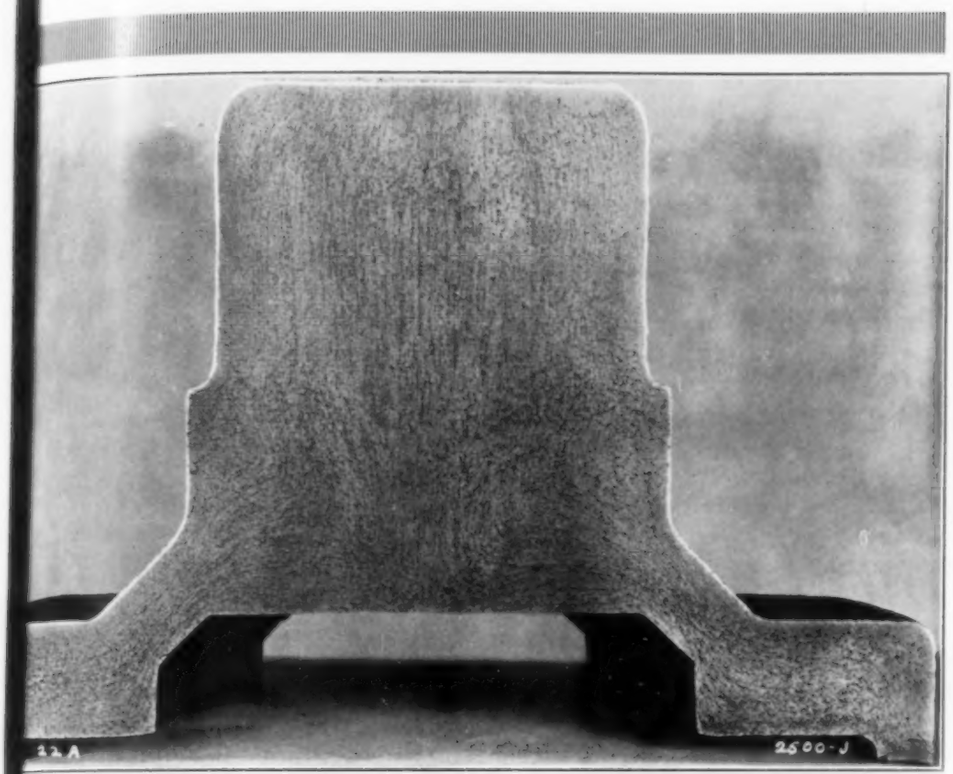
"Others have advanced the idea," said Mr. Graham, "that in the cutting operation the path of rupture follows preferred planes along which the separation proceeds rather easily, and that the grain boundaries interrupt the progress of the line of separation along these preferred planes. We find it difficult to believe that the amount of additional energy expended at the grain boundary is very large as compared with the normal energy required in forcing the path of rupture through the crystal itself," continued Mr. Graham.

"To get a clearer picture we must bear in mind that the constituent of steel designated by metallographists as 'ferrite' is a very complex entity. It consists of alpha iron which may hold various elements in dispersion, ranging from molecular to microscopically visible particles. Such differences in ferrite quality manifest themselves in appreciable differences in work-hardening capacity, grain growth characteristics, and nature of the plastic deformation under static and dynamic loads.

"There is a rather wide range of variation in the quality of the ferrite in separate heats of steel made to the same analysis of common elements, and this is more important and fundamental than mere grain size.

"The situation as to relative grain boundary effects is very much as would confront a hunter who walks across country, through fields and over fences. To some extent the difficulty of his progress would depend upon the number of fences which he had to climb, and, therefore, the size of the fields would be an important factor, since such size would determine the number of fences which must be climbed. Even under best conditions, however, the effort required to walk across the fields would still be appreciable as compared to that required to climb the fences. If the fields were overgrown with tangled brush,

A Number of Papers Have Recently Been Published About Bessemer Steel, Drawn From a Continuing Investigation Directed by H. W. Graham, General Metallurgist of Jones and Laughlin Steel Corp. Photo is by Bachrach



Cross-Section of a Forging After Deep Etching. It is very dense — that is, has a minimum of fiber appearing — and has good machining qualities. Mr. Sanders demonstrates that coarse grained steel more readily produces such dense forgings

the amount of effort required to climb even a relatively high fence might be insignificant as compared to that required to cross the field."

There was no disposition on his part to question the fact that grain size had much to do with the machinability of normalized steels, yet Mr. Graham felt that heat treatment gives an additive effect, superimposed on an inherent quality, and it is the latter which he is wishing to improve, fundamentally.

Grain Size for Gear Forgings

W. E. Sanders, metallurgist with General Motors Co., presented some further data substantiating the facts developed by him on density and machinability of gear forgings at Muncie Products Division and published in METAL PROGRESS, July, 1932. This early study was the first rational study of "fiber" (determined by pickling a sectioned forging) as it affects the properties of the piece. It indicated that the flow lines were less and less in evidence as the metal was more and more strongly compressed in the forging dies, and that these strongly compressed steels normalize more uniformly and can be machined at greater feeds and speeds. His theory is that improper forging — especially too heavy or violent changes in shape in a single die or stroke — will "tear the fibers, as in a tensile test, before the internal structure can adjust itself to the movement. This slipping, or tearing, is indicated by voids or cavities brought out by acid etching," and this produces the familiar appearance of flow lines or fiber. Forgings which do not etch in this pronounced manner, he says, are "denser." It was early discovered that slugs, progressively coarsened by higher and longer heating, forged into progressively denser gear blanks, "which suggested that a coarse structure has more ductile fibers."

Further experiments on a series of ingots of the same composition whose McQuaid-Ehn grain size varied from 4 to 9, forged under the same conditions, showed that "the coarse grained ones, by virtue of greater ductility and longer fibers, showed less tearing in the upsetting" and therefore made denser forgings. "A certain amount of evidence is also at hand which indicates that electric furnace steels will run more consistently dense than open-hearth steels," continued Mr. Sanders.

"We must also bear in mind that there are many variables in the actual forging process which affect density. These alone, if corrected, will improve machinability and durability to a great extent in any grain size specification. First, the steel should be purchased on density and grain size specifications, in addition to the chemical specification. Second, the forging dies must be designed to effect maximum compression on the metal in the forging. Third, the furnaces should be of a design that will insure uniform temperature throughout."

Dense forgings are more readily machined

into gears, as shown in 1932. Recent tests on the drilling properties show that 8% more heat is developed at the drill point in less dense forgings, an equal differential is found in the torsion indicator with wide fluctuations indicating chattering, and 26% more power and time is required for equal depth.

"By correcting the forging practice, an improvement in machinability may be expected from 15 to 50%, depending on the operation," in Mr. Sanders' opinion. "Speeds and feeds may be increased from 11 to 60% and tool life increased in like proportion.

"To a gear manufacturer there are other things of major importance besides machinability, that is, changes in the heat treatment. With a dense, homogeneous structure, distortion becomes more uniform in hardening, enabling accuracy of spacing maintained on hobbing machines within 0.0002; contour within ± 0.00025, and when the pieces return from the fire you can expect 0.0004 to 0.0005-in. change in contour and no apparent change in spacing. The gears going to the hardening department with concentricity of less than 0.0001 return with 0.0015 in. With the control maintained on the steel and forgings, it is a simple matter to correct the hob by grinding more or less rake in the cutting face, thus compensating for the regular fire distortion.

"Durability is likewise effected by the reduction in tooth growth and distortion, which makes for better alignment and tooth contact."

Men From the Automotive Industry Always Flock to the National Metal Congress. Prominent among them was J. M. Watson, metallurgist of Hupp Motor Car Co. and past president, American Society for Metals

Grain Size vs. Toughness of S.A.E. Steels

Last January H. W. McQuaid of Republic Steel Corp. wrote an article for METAL PROGRESS on the trend in requirements for plain and alloy steels. It outlined many of the points in his paper prepared for the convention on "Effect of McQuaid-Ehn Grain Size on Hardness and Toughness of Automotive Steels." The latter summarized a wealth of experience, rather than a lot of numerical data — in fact, he defined hardness as the ability to resist wear and abrasion (best indicated by the file) and toughness as the ability to absorb stresses beyond the elastic limit without concentrating them at some defect in surface or design and thus causing failure (measured to some degree by the impact test).

He pointed out that the McQuaid-Ehn test merely indicated grain size at a certain temperature (1700° F.) which in turn was an indication of grain growth — since steels have been supposed to grow in austenitic grain size as the temperature is raised above the critical. Coarse grained steels (by the McQuaid-Ehn test) do so; fine grained steels may grow but slowly until 500° F. above Ac_3 is passed. Many plants are now equipped to normalize steels at 1800° F. and higher, and in such equipment "fine grained" steels can be coarsened for easy machining, and then refined by an ordinary quench and draw and present the advantages of a fine grained steel, namely, small warpage and good toughness. (Hardness at the surface is independent of grain size, when pieces are properly hardened.)

Thus chromium-vanadium steels (S.A.E. 6100 series) coarsen very easily above 1700° F., but are usually fine grained below 1650 — an ideal condition for applications requiring maximum machinability. On the average, fine grained normal steels react differently from fine grained abnormal — where a maximum combination of toughness and hardness is required Mr. McQuaid prefers the latter.

McQuaid-Ehn grain size is specified by most metallurgists in automotive plants, either directly or indirectly, about as is indicated in the following paragraphs. At the present time the principal distinction is between fine grain and coarse

E. G. Brick, Recently Graduated From Long and Efficient Services With Cadillac Motor Car Co., and Secretary of the Detroit Chapter. Is Now With Youngstown Sheet and Tube Co.

grain. In Mr. McQuaid's opinion carbon steels should nearly always be fine grained; alloy steels should be specified either coarse or fine after acquiring a good idea of what the purchaser really needs.

Specifications by Classes

Plain carbon steels, not heat treated (such as S.A.E. 1000, 1100, X1315) should have a coarse grain for maximum machinability and best cold heading properties. Fine grain is better when subjected to shock loads or occasional severe overstress.

Plain carbon steels, heat treated, but not carburized (S.A.E. 1040, Ford EE): Generally fine grained, shallow hardening type. When oil hardened to high Brinell, use coarse grain type. Coarse grain in very heavy parts such as large truck front axles. Medium grain in passenger car front axles, and on parts with heavy and light sections — the heavy sections will harden satisfactorily without cracking the light sections.

Plain carbon case hardening steels (S.A.E. 1010, X1315): Fine grain for minimum distortion; coarse for machining and hardening. Generally recommended as fine as possible consistent with satisfactory surface hardness, so as to avoid corner cracking of parts hardened very deeply, and grinding cracks. Used in camshafts, small gears, differential parts, brake parts and washers.

Plain carbon steels, high in carbon (S.A.E. 1060, 1095) are useful for flat springs, valve springs, and coil springs. Fine grain is best to avoid stress concentration. Bumper bar stock may be medium grain size to coarse, for oil hardening.

Medium manganese steels, with or without sulphur (S.A.E. 1340) are used in many important parts. Fine grain is preferred, but depends on analysis and quench. Such a steel may be used by the same company for front axles, cranks, cams, rocker arms, starter rings, and connecting rods — obviously of different requirements as to hardenability, yet a matter which is commercially controlled by grain size. Coarse grained, deep hardening types are avoided for connecting rods and other parts with thin webs, on account of their liability to shearing and flash-line cracks, and losses in heat treating.

Low carbon, low alloy, case hardening steels (S.A.E. 2015, low chromium-nickel, vanadium gear steel): Specify fine grain for gears, remembering danger of trouble with surface soft spots if too fine and abnormal. For heavy parts, coarse grain is preferred; for direct quenching, fine grain is preferred. Fine grained gears distort less in hardening, and minimize noise from irregular tooth contacts.

Low carbon, medium alloy steels (S.A.E. 3115, 6115, 4615, 2315): For gears and bearings, fine grain is best. Fine grain for direct quench. Coarse grain for heavy sections for maximum core properties. For maximum machinability with increased distortion coarse grain is preferred, unless specially normalized.

Low carbon, high alloy types (S.A.E. 2512, 3300, 3400, case hardening 3.5% nickel, molybdenum, Krupp): Used for truck and bus gears and very heavy duty case hardened parts. Should have fine grain for all applications.

Medium carbon, medium alloy steels (S.A.E. 3130, 4130, 5140, 6140): Used for passenger car and light truck axle shafts, arms, knuckles, some connecting rods, cranks, and oil-hardened gears. Should be fine grained in all applications where so-called toughness is important. In heavy sections where deep quench is required medium or coarse grain is best.

Medium carbon, high alloy steel (S.A.E. 3240, 3340, 3440, chromium-nickel-molybdenum): Used for heavy duty gears, axle shafts, highly stressed parts, and should always have a fine grain.

Albert Sauveur — An Appreciation

In his honor has been established the Albert Sauveur Achievement Medal

By Herbert M. Boylston

A YOUNG chemistry student entered a quiet office in the Rotch Building at Harvard University in 1903. He had come to meet the man who knew how to take photographs of metal sections through the microscope. He found a young man with dark curly hair and moustache, sitting at his desk, smoking a pipe and reading a technical magazine. As Dr. Sauveur looked up from his reading there was a twinkle in his eye and a friendly smile enveloped his face as he greeted the student who wished to learn more about metallography and the hidden secrets of metals. In a modest manner he described his own experience and the light of enthusiasm was in his eye as he explained how simple were the operations of preparing specimens for microscopic examination and photomicrography. This was the first contact the writer had with Dr. Albert Sauveur, now dean of American metallurgists.

Not long ago the writer visited him in Falmouth, a Massachusetts village where he was spending a vacation. The same spirit of friendliness was still there, the same modest demeanor, the same clear-cut logic in his discussion of technical subjects, the same quick understanding of problems placed before him — but this was thirty-one years later and the curly hair was now quite gray.

Always courteous, patient, making known his requirements to his assistants or students by suggestions rather than by direct order, keen minded in grasping new ideas, slow to accept half baked theories and rejecting false reasoning, Dr. Sauveur has been and still is a great teacher, a great scientist and a great man. Tireless in his efforts to make things clear to his hearers or his readers, of an untiring and resourceful turn of mind in overcoming difficulties of manipulation and the short comings of available apparatus, Dr. Sauveur proved the usefulness of the microscope for metallurgical work as early as 1891. He has led and inspired a constantly increasing group of disciples for the last forty years in their efforts to learn and appreciate the relations between the microstructure and the physical properties of all kinds of metals and metallic alloys.

Fighting against a handicap of inadequate apparatus and insufficient funds for expendable supplies, Dr. Sauveur firmly established a new science of metals in the United States.

His many writings are clear and easy to understand, forceful, yet his thoughts are clothed in beautiful flowing English, free from ambiguity and always to the point. His masterpiece, "The Metallography and Heat Treatment of Iron and Steel" has been a bible and a textbook to a great number of students young and old, including college men, operating men and executives.

As the pioneer in the subject of metallography he not only developed the science itself but did much to improve the apparatus for examining metals — including polishing apparatus, the microscope itself, photomicrographic equipment and all the accessories that go with it.

He has acted as expert in many patent litigations and other investigations arising from failures of metals. In the early days he acted as editor and publisher of *The Metallographist* and its successor the *Iron and Steel Magazine*. The present writer collaborated with him in 1908 to publish a little book called "Laboratory Experiments in Metallurgy" which is now out of print.

He received the Doctor of Science degree from Case School of Applied Science in 1921, from the University of Grenoble, France, in 1924 and from the University of San Marco, Peru, in 1925. He received the degree of Doctor of Engineering at Lehigh University in 1926. He received the Bessemer Medal of the British Iron and Steel Institute in 1924.

Dr. Sauveur has been a teacher of metallurgy at Harvard University since 1897 and for a number of years has held the title "Gordon McKay Professor of Mining & Metallurgy." He received the first award of the new Albert Sauveur Achievement Medal of the American Society for Metals in New York on October 4, 1934. He was awarded the Elliott Cresson Medal by the Franklin Institute of Philadelphia in 1913. He is an officer of the Order of Leopold, Belgium, and Officier d'Academie, France. He is a member of the National Academy of Sciences, a chevalier, Legion d'Honneur, and a Fellow of the National Academy of Arts and Sciences.

American Tool Steels

manufacture and testing

An innovation at the annual convention of the American Society for Metals was a course of lectures on tool steel, given by one of the leading authorities. We are able to print here only some brief extracts concerning the first phase of this broad subject. The entire text of Mr. Gill's five lectures, appraising the selection, properties, and uses of all the commercial tool steels, comprises a 140-page book published by the Society at $2 (in cloth $2.50).

by James P. Gill
Chief Metallurgist
Vanadium-Alloys Steel Co.
Latrobe, Pennsylvania

THERE are four methods of melting tool steel that are of interest. First the crucible process, which is now almost obsolete in the United States, as there are only a few furnaces maintained in a condition to operate and these furnaces do not operate continuously. Next is the basic open-hearth; it is generally believed and with some justification that this method of melting does not readily lend itself to the making of highly alloyed tool steels, due to the fact that during the melting operation the steel is continually subjected to oxidation. Nevertheless, carbon tool steels and low alloy tool steels of good quality can be manufactured with proper care and procedure.

Basic electric arc furnace is at the present time the most widely used method of melting quality steels, and almost the only method of melting highly alloyed tool steels (with the exception of the small amounts made in the induction furnace). It is the refining period which offers the real advantage of the electric furnace over the open-hearth in that the open-hearth during this period has oxidation continuously proceeding, while in the electric furnace the atmosphere might be considered stagnant and therefore not reacting with the slag or charge.

The refining operation is based largely upon the reactions between the steel and the slag which accomplish three distinctly different purposes and must be carried out separately in sequence. First is the removal of the oxidizable elements, principally carbon and phosphorus but sometimes also manganese and chromium. When these elements are present in sufficient amounts, the slag is removed after their oxidation has been completed and a new slag is then added.

If the steel is an alloy steel and it is only necessary to lower the carbon in the charge, the slag is not pulled and the oxides of the alloying elements that have accumulated in the slag are reduced back to the metallic state and returned to the steel. This is the second reaction, namely, the reduction of oxides in the slag; it may be carried out by the use of finely divided carbonaceous material, by calcium carbide, or by a metallic reducing agent such as ferrosilicon.

The third reaction is the deoxidation of the steel; it consists in converting those oxides that are soluble in the steel (such as FeO and CO) into insoluble ones and their separation from the metal by gravity. Such reactions are facilitated by the addition of so-called double deoxidizers such as calcium silicide or aluminum-silicon alloys to make more fusible compounds.

James P. Gill Delivered a Series of Lectures on Tool Steels — One of the Unusual Features of the Last Convention

Desulphurization of the bath also takes place during the oxidation of the slag and steel. Another advantage of the basic electric process is due to the fact that after refining the steel can be held with substantially no further reactions, thereby permitting an analysis of the molten steel and adjustments in composition; temperature may also be readily adjusted for casting.

Coreless induction furnaces form the fourth group of melting units. The coreless induction furnace seems to have a distinct disadvantage, due to the fact that the metal as soon as molten is under continuous agitation, therefore causing a continual mixing between the steel and the slag. While it is an excellent tool for the melting of small heats, nevertheless the quality of the steel which it produces does not appear to bear as favorable a relation to the steel melted by the electric arc furnace as the earlier proponents of the furnace claimed.

Casting, Forging, Rolling, Finishing

The proper casting of quality steel is of great importance in that the temperatures should be such that the ingot may cool with the proper crystal size. The mold design and ingot size are also important so that piping and porosity may be at a minimum, and the distribution of segregates in highly alloyed steels be under control. There is no empirical rule pertaining to all steels that the cross-section of the ingot should be so many times the cross-section of the finished bar, as it has been found that oftentimes a better distribution of the segregate may be obtained by the use of smaller ingots and less reduction than by the use of large ingots and more reduction.

Coarse, crystalline ingot structure is refined by rolling or forging (pressing is not generally used in the manufacture of tool steels). The final grain size is particularly dependent upon the temperature at which the last mechanical work was completed.

In rolling, the flow of the metal is continuous and almost entirely in a longitudinal direction. Therefore, any segregates are usually simply elongated by rolling and not broken apart. Forging by hammers is similar to a kneading action. Since the hammer strikes a sudden blow, compressing the metal in a narrow area, it has a tendency to tear apart any segregates which may be present in the steel. Thus has come about the axiom that all tool steels should be hammered before they have been finally shaped by rolling. This is true for highly segregated steels but quality carbon tool steels and other low alloy steels and steels which are not highly segregated can be rolled into bars that will compare favorably in physical properties with forged bars.

Heating of bars for rolling and forging must be done at a rate which will not cause checking and must be sufficiently slow that it is uniform across the section of the piece. Temperature must be held within a comparatively narrow range, which is a balance between plasticity and grain size.

Annealing is usually considered essentially for the purpose of softening the steel but the operation is also used to remove stresses, to alter the physical properties, to refine the crystalline structure and even remove gases; it is therefore quite important and affects the physical properties of the steel to a much greater degree than merely softening. Annealing implies slow cooling through the critical range — 30 to 50° F. per hr.

Final inspection of tool steel is both costly and time consuming, but regardless of the ability of the manufacturer, the quality of his product will depend to a great degree upon the intelligence and thoroughness used in his inspection.

A classification based on analysis of several hundred brands of widely used tool steels is presented in the table overleaf. Each type can be

further subdivided, and at least 95% of all tool steels manufactured would fall into one of these main types. In most instances, examples of any type will contain additional elements in accordance with the opinions of the manufacturer and consumer.

It must not be assumed that a direct comparison can be made of the physical properties of steels of a certain type as made by two different manufacturers. By varying the alloys within the limits given in the table and by the addition of other alloys a great variation may be found, and practically every manufacturer of tool steel makes one or more "grades" of each type that is listed.

The table also contains data on properties which are important for determining the adaptability of a steel for any specific application. In addition may be mentioned machinability and cost. It is not always possible to obtain all the desired physical characteristics in any one steel and most selections will represent something of a compromise. After having selected the proper type, we can consider what effect variation in composition and heat treatment may have to adapt it more particularly for the tool in question.

A user of tool steels has a twofold reason in testing. First, a method of inspection or testing which will insure a uniform product once the desired type of steel has been selected, and second, what might be termed an evaluation test, that is, the adaptability of the steel for the specific use intended.

Testing of Tool Steels

Tensile tests are of little value on hardened tool steel, primarily due to the difficulty of pulling along the exact axis of the specimen; consequently, very hard specimens will usually break from a shearing action. Impact tests are also quite erratic.

Torsion tests have been used for many years by most makers of small tools, such as taps and drills. A worthwhile improvement has been advocated by Emmons in the use of a standard specimen and he suggests the term "coefficient of toughness" for the product of the ultimate torque and the degree of twist. In torsion testing the stresses are distributed over a comparatively long length and thereby the variations resulting are comparatively small.

Hardness tests are a necessity in determining certain qualities of tool steels, and many methods are available, including the file. A direct comparison of the values obtained by the various testing machines cannot be made, and attempts to do so may cause erroneous values as to hardness. Thus, high speed steel and carbon tool

Classification of American Tool Steels According to Type Analysis

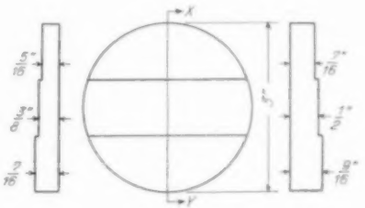
Content of Principal Alloys				Type	Major Characteristics Affecting Utility						
Carbon	Tungsten	Chromium	Others		Working Hardness	Wear Resistance	Toughness	Warpage	Hot Hardness	Quench Medium	Depth of Hardening
0.60 to 1.40				Plain Carbon Tool Steel	*	Low	*	High	Low	Water	Low
0.60 to 1.40			0.15 to 0.40 V	Carbon-Vanadium	*	Low	*	High	Low	Water	Low
0.50 to 1.40		0.30 to 0.90	none, or 0.15 to 0.25 V	Chromium-Vanadium, or Low Chromium	*	Low	*	High	Low	Water	Medium
1.00 to 1.30	1.0 to 2.0	0.50 to 1.50	0.15 to 0.30 V	High Chromium, Low Tungsten	C-62 to C-65	Medium	Medium	Low	Low	Oil	Medium
0.80 to 1.00	0.4 to 0.6†	0.40 to 0.60†	1.00 to 1.75 Mn	Manganese Oil Hardening	C-58 to C-62	Low	Medium	Low	Low	Oil	Medium
0.45 to 0.60	1.0 to 2.0	1.0 to 1.5	0.15 to 0.30 V	Tungsten Alloy Chisel	C-50 to C-55	Medium	High	Low	Medium	Oil	Medium
1.10 to 1.40	3.0 to 5.0			Finishing Tool Steel	C-63 to C-66	Medium	Low	High	Medium	Water	Deep
0.80 to 1.00		3.0 to 4.0		Chromium Hot Work	C-45 to C-50	Medium	Medium	Low	Medium	Air or Oil	Deep
0.25 to 0.45	8.0 to 15	2.5 to 3.5		Tungsten Hot Work	C-45 to C-55	Medium	Medium	Low	High	Air or Oil	Deep
0.25 to 0.50	3.0 to 7.0	3.0 to 7.0		Chromium-Tungsten Hot Work	C-43 to C-50	Medium	Medium	Low	High	Air or Oil	Deep
0.50 to 0.65			1.5 to 2.5 Si, 0.75 to 1.00 Mn	Silicon-Manganese Tool Steel	C-50 to C-57	Medium	Medium	Medium	Medium	Water	Medium
1.50 to 2.25		10 to 15		High Carbon, High Chromium	C-58 to C-66	High	Low	Low	High	Air or Oil	Deep
0.50 to 0.80	14 to 20	3.0 to 4.5	0.75 to 2.25 V	High Speed Steel	C-62 to C-66	High	Low	Low	High	Air or Oil	Deep
0.60 to 0.80	14 to 20	3.0 to 4.5	0.75 to 2.25 V, 2.5 to 12 Co	Cobalt High Speed	C-64 to C-66	High	Low	Low	High	Air or Oil	Deep

† With Manganese on high side these may be absent

* Usual working hardness and toughness depends on carbon content

steel, when hardened to Rockwell C-65 will show respectively 85 to 87 and 98 to 100 when tested by the scleroscope.

Abrasion tests should be of great value in determining a highly important physical property of the steel, but in such tests it is most difficult to obtain consistent, uniform, and satisfactory results. A number of different types of machines have been designed and it is probable that no two people have ever made the test in the same manner. Anyone who wishes to conduct wear tests must do so under conditions which he thinks are of most value to him and repeat the tests a sufficient number of times that at least he may be satisfied with the conclusions. (Probably no one else will be.)



Step-Down Specimens for Determining Depth of Hardening of Carbon Steel Tools After Quenching

Hardenability tests are valuable in determining the depth of case, susceptibility to overheating or grain growth, maximum hardness obtainable, minimum temperature at which maximum hardness may be obtained, tendency to soft spots, tendency to soft skin or decarburization and movement. A thick specimen of almost any shape will give some indication as to the probable depth of case. More accurate information can be obtained by using the step-down test, in which disks as illustrated are machined to different thicknesses, hardened, and broken.

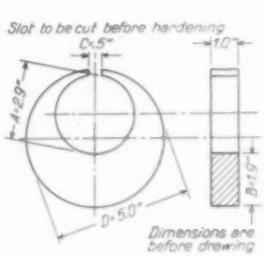
Susceptibility to overheating and maximum hardness obtainable may be determined from samples hardened from different temperatures at increments of 25 or 50° F. Tendency to soft spots is determined by quenching 2-in. cylinders in water and etching 30 min. in 1:1 HCl solution at 180° F. The McQuaid-Ehn carburizing test may also be used to determine hardenability.

Soft skin or decarburization depends upon furnace atmosphere, so the regular hardening procedure for finished tools must be carefully followed. After the specimens are hardened, a file will often show whether or not a soft skin is present, or the Monotron hardness tester may be used. The surface may be ground in steps of 0.005 in. and hardness readings taken. A fracture of the specimen may indicate it, but usually does not.

Movement during hardening is a most important property, but it is most difficult to apply test results to allow for movement likely to take place in a complicated die. A ½-in. cylinder 6 in. long is most generally used for determing the tendency to lengthen or shorten on hardening. It is necessary to use quite large specimens (that is, something in the vicinity of about 3 or 4 in. thick and 12 in. square, machined flat) when it is desired to determine the tendency of the steel to bulge on hardening. Various governmental agencies have advocated the use of the specimen shown at the foot of this page. The specimen is measured at A, B, C, and D before and after hardening.

Magnetic tests may be of several types, one involving the change of permeability resulting from non-uniformity. It has some uses in testing finished parts, but it is not so good for internal flaws in bars, as the intensity of the change will depend on the relationship of the size of the flaw to that of the bar; also variation in bar size and condition affects the results. Another method, known as the "magnaflux," is quite valuable in locating flaws in the surface; it depends on sprinkling a magnetic powder on the surface of the specimen which is magnetized, and shaking off the excess.

Fracture tests are of considerable value in judging certain characteristics of tool steel but can only be of value to those who have had long experience in observing and comparing fractures of the same type of steel. It is practically impossible to describe or to photograph a fracture so that the description or photograph will correctly portray its characteristics. The play of light upon a fracture gives it a certain characteristic appearance and this cannot be photographed. Thus, about the only way that the actual appearance of a fracture can be conveyed by one person to another is by the actual sample itself, freshly broken and untarnished.



Specimen for Measuring Movement During Hardening. If C is measured as annealed and as hardened and drawn, the gain for typical die steels is as follows: 0.010 in. for manganese oil hardening steel; 0.006 to 0.018 in. for chromium-tungsten hot work steel; 0.004 to 0.015 in. is expected for high carbon, high chromium steels

Deep Etch Tests

The deep etch test, which is a type of macroscopic test, has become of quite general use during the last few years. It is much more difficult to draw proper conclusions from the test than it is to make it and the conclusions arrived at are often a matter of opinion, the value of which can be no greater than the experience and judgment of the investigator.

The test is quite valuable in determining many types of discontinuities within the metal such as hammer bursts, pipe, seams, laps, checks, flakes, soft spots, and grinding cracks, decarburization or carburization, depth of case and flow lines from rolling or forging.

However, "porosity" or "open grain" as indicated by the deep acid etch test may be neither porosity nor an open grain but simply a selective attack by the acid. Etching pits or holes will develop from the presence of non-metallic inclusions as well as from metallic segregates etching out of the steel and leaving a pit. Therefore, to determine the difference between the two requires a further test, either under the microscope or by comparing specimens with one another in different conditions of heat treatment.

Dendrites and pattern effect are often beautifully developed by the deep acid etch test but even with the knowledge of the presence of either or both, conclusions cannot be readily made as to what effect they may have upon the physical properties of the material.

The microscope is most valuable for determining the distribution of metallic segregates, and inclusions of any nature, when they exist, and to measure depth of case, decarburization, or grain size. It is used in conjunction with other tests, and is one method in which the testing is usually done by someone of considerable specialized training.

Evaluation of Tool Steels

Evaluation is the determination of the adaptability of a steel for a specific use. The procedure appears to be different for almost every user. Some study the physical tests; others will devise tests to emulate the operation, while a great many will simply make a tool or die from the steel they wish to test and place it into regular production. Those who can eliminate certain steels by physical testing and then proceed with a shop test probably arrive at a more logical conclusion.

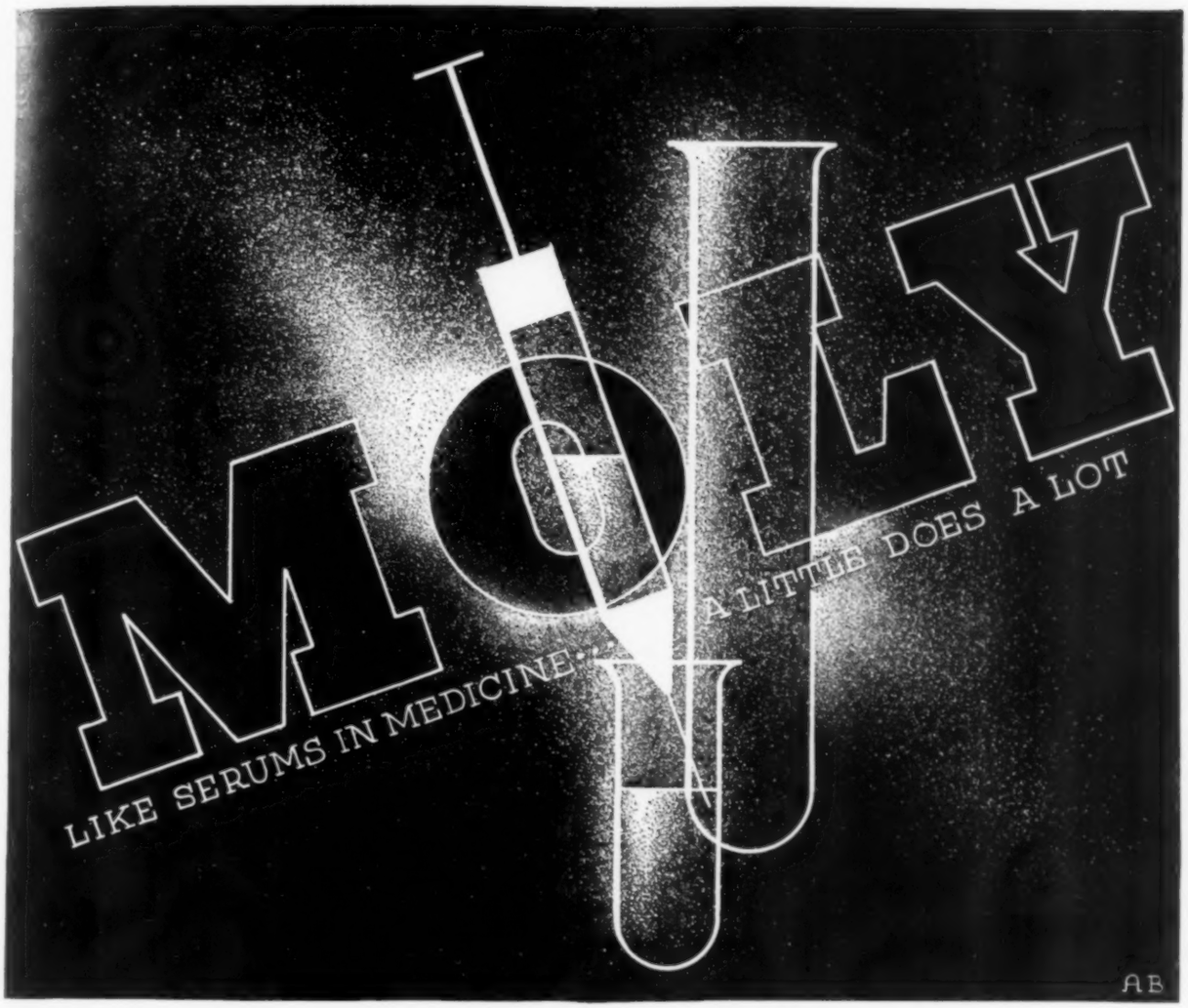
Much data have been accumulated on the cutting ability of lathe tools, milling cutters, and twist drills. It appears that tests made with milling cutters will give the more consistent results, probably because it has many cutting edges working only a part of the time and chipping a single edge may not cause an immediate failure of the entire tool.

Cutting tests that might be considered at all reliable require unusual care in the preparation of all materials involved. Strict attention must be paid to heat treatment, design, and grinding of the tools, uniformity of the material being cut, and rigidity of the set-up. Even under these conditions, tools made of the same steel will oftentimes show a variation of from 200 to 400%!

Anyone who has studied cutting tests must doubt how far he can accept the results. To the author it seems that the greatest value of cutting tests is to compare different types of steel, rather than to compare steels of the same type and little difference in composition — unless a large number of tests can be averaged.

Many users of tool steel will tell you that to determine the quality of a tool steel it should be placed in actual production. The big problem then is to find a job on which they can be tested which will continue a sufficient length of time to finish the test. This is the one chief deterrent to the testing of tool steels in this manner. A single tool or even several tools may not be an indication of what the tool material will do, as accidents and other causes beyond the operator's control may cause a premature failure. A sufficient number of tools must be tested so that an average of results may be indicative.

Many large users of tool steels have gone to rather elaborate systems to obtain a true indication of material placed in test. Several years ago one automobile maker purchased about ten different brands of high speed steel, each in amount to represent approximately 10% of his requirements for six months. Tool were numbered and records accurately kept. At the end of every two weeks a tabulation was made, ranking the production records of the steels in order. At the end of six months the steel which made the best showing received 80% of the business for the following six months, but 20% was given to the other nine producers and the same records were maintained. If at the end of any six months' period, one of the other steels made the best showing during that period, that producer was then given the bulk of the business for the following six months.



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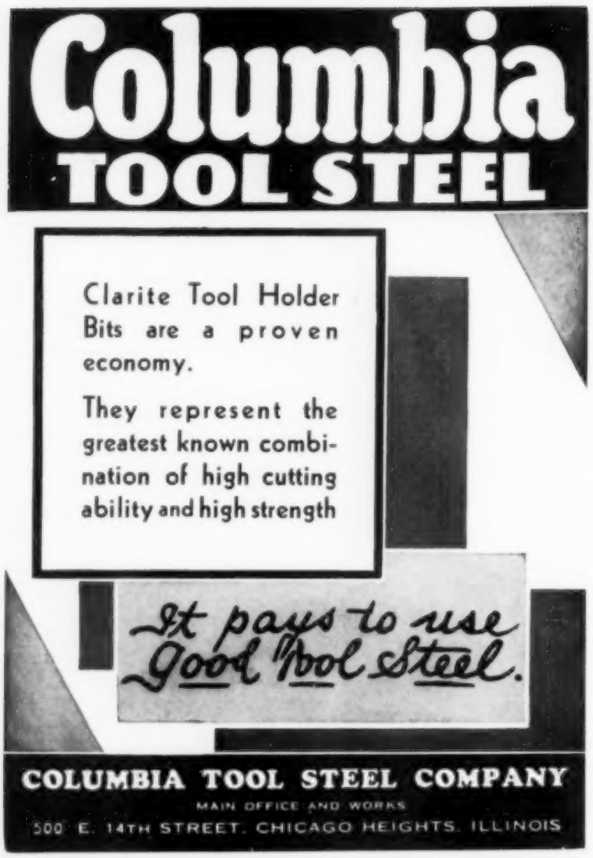
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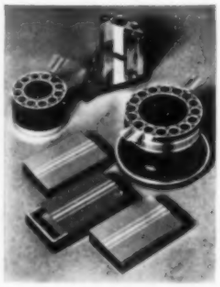

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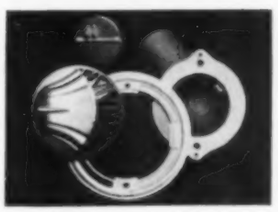

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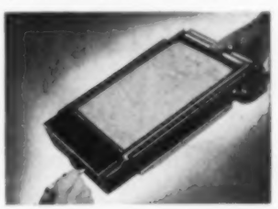

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In powdered form NORBIDE (Norton Boron Carbide) is an extremely hard abrasive and is used for lapping the cemented carbides and for other jobs where diamond dust has been necessary. Metallurgically, it has possibilities as an economical source of boron.

In molded form NORBIDE (Norton Boron Carbide) is extremely resistant to abrasion and is used where an exceptionally hard, smooth material is required. As a lining for pressure blasting nozzles, for example, it shows a thousand times the life of ordinary nozzles. Other outstanding uses range from thread guides for the rayon industry to extrusion dies for graphite, porcelain, and other materials of an abrasive nature.

We'll be glad to discuss its possibilities with you.

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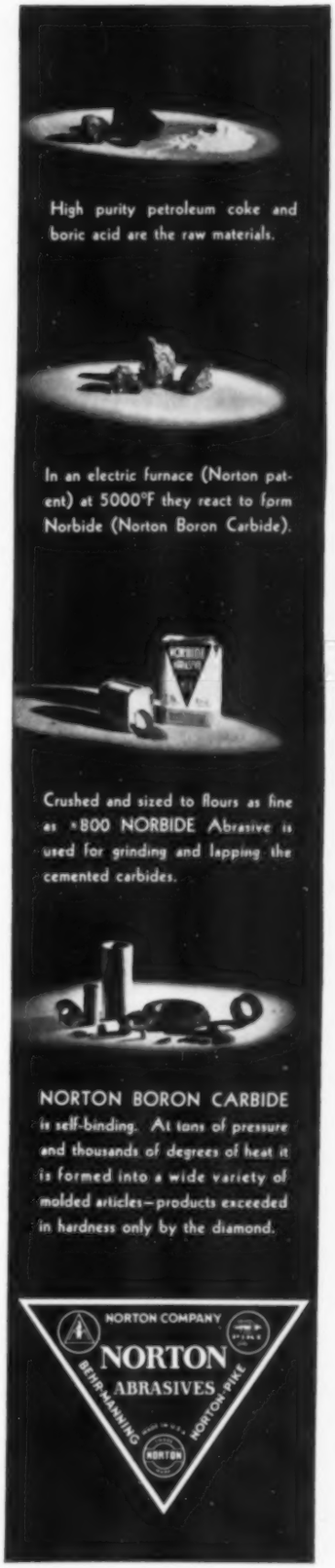

High purity petroleum coke and boric acid are the raw materials.

In an electric furnace (Norton patent) at 5000°F they react to form Norbide (Norton Boron Carbide).

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NORTON BORON CARBIDE is self-binding. At tons of pressure and thousands of degrees of heat it is formed into a wide variety of molded articles—products exceeded in hardness only by the diamond.

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Free Literature

Long-Lasting Sheet Iron

"Thumbs Down on Rust," says Republic Steel Corp., and cites three reasons for the high rust resistance of Toncan Iron. A number of typical applications are illustrated. Nv-8.

Air Draw Furnace

Hevi-Duty Electric Co. offers a folder on their box type air draw furnaces for tempering, drawing, preheating, or annealing. Two types are available, one for temperatures up to 750° F., and one for 1250° F. Nv-44.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Cold Drawn Shapes

Many applications of cold drawn squares and flats are enumerated by Union Drawn Steel Co. in this folder. Sizes, grades of finish, and compositions available are listed. Nv-83.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Hardening Furnaces

The C. I. Hayes Certain Curtain electric furnace for the range 1200 to 1850° F. is described in this bulletin. Its applications to hardening of carbon, stainless, and alloy tool steels and to preheating high speed steel are discussed. Nv-15.

Grinding Cemented Carbides

A complete and detailed treatise on this important problem has been issued by the Carborundum Co. Special wheels and grits for the various commercial grades of carbides are given and many practical pointers are included. Nv-57.

The Lindberg Control

The Lindberg Control announced a few months ago for electric furnaces is now available for fuel fired furnaces. Controlling the input of fuel fired furnaces eliminates the lag caused by the protecting tube around the thermocouple and results in straight line temperature control. Nv-66.

Properties of Stainless

Carpenter Steel Co. offers (to manufacturers in U. S. A. only) a handy pocket size slide chart which gives at a glance a summary of technical data on all Carpenter stainless steels. Bulletin Se-12.

Steel Specifications

A handy, up-to-date specification sheet for carbon and alloy steels is offered by Timken Steel & Tube Co. On one page are printed analyses of all important types of Timken steels. Bulletin Jy-71.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Non-Ferrous Annealing

General Electric Co. describes bell-type furnaces for annealing non-ferrous metals in a new folder which gives many data on operation and performance. Description is from technical rather than sales angles. Bulletin Ar-60.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

High Strength Steel

Cromansil steel, a development of Electro Metallurgical Co., has high strength and good ductility "as rolled" and is thus fine for structural applications where its great strength saves much dead weight. Bulletin Je-16.

Uses of Molybdenum

Climax Molybdenum Co. offers a useful 50-page booklet showing the benefits conferred by alloying molybdenum with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Au-4.

11 Stainless Steels

Pertinent facts on 11 different types of Bethadur and Bethalon corrosion resisting steels are presented in a 40-page Bethlehem Steel Co. booklet. Advantages and limitations of each type are frankly presented. Bulletin Fb-76.

Aluminum vs. Corrosion

In a carefully prepared booklet of Aluminum Co. of America, effects of various corrosive agents upon aluminum and its alloys are described in detail. It is an excellent source of information on this subject. Bulletin Sp-54.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Blast Cleaning

A rugged blast cleaning cabinet for rapidly cleaning small work is described in a recent folder of Pangborn Corp. Full information on the operation of this machine is presented; many drawings and pictures are included. Bulletin Je-68.

Homo Tempering

Leeds & Northrup Co. introduces a specialized Homo furnace for tempering heavy, dense loads of small articles. Production can be multiplied as much as four times. Complete description is given in Bulletin Je-46.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Kanthal Alloys

S.K.F. Steels, Inc., offer a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

Structural Bronze

Olympic Bronze, a high copper alloy containing silicon and zinc, is suggested by Chase Brass & Copper Co. for structural and engineering purposes. A new booklet gives many interesting details about its use. Bulletin M-59.

Copper Welding Rods

American Brass Co. describes in complete detail the welding properties and individual characteristics of 14 different copper alloy welding rods. The 16-page booklet also makes specific recommendations of welding procedure. Bulletin Je-89.

Heat Controller

As a companion instrument to their new indicating pyrometer, Foxboro Co. has introduced a new and inexpensive temperature controller which is dependable and easy to operate. Close control of temperatures is possible. Bulletin Mr-21.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Localized Heat Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is offered to those interested in pickling. A feature is a table of inhibitor strengths recommended for pickling various steels. Bulletin Ap-95.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

Oxwelding Stainless

Linde Air Products Co. has published a handbook of instructions for successfully welding corrosion resisting steels by the oxy-acetylene process. Welding procedures and weld treatments are carefully explained. Bulletin Jy-63.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

X-Rayed Alloy Castings

Electro Alloys Co. describes their X-Ray inspection of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Bulletin Oc-32.

New Tempering Furnace

American Electric Furnace Co. has a new, low-priced electric air tempering furnace. It heats to 600° F. in 5 min. and to 1000° F. in 15 min., transferring heat to work 50 times faster than still air and 6 times faster than salt. Bulletin Mr-2.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a booklet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Optics in Metallurgy

Many uses for optical instruments in metal working are described in a new booklet of Bausch & Lomb Optical Co. Photomicrography is prominent, but this well illustrated booklet shows many other interesting optical instruments. Bulletin No-35.

Atmosphere Furnaces

An interesting folder of Surface Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

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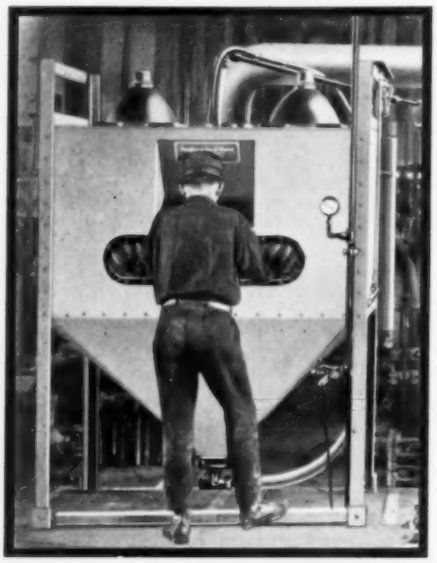

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Annual Convention

Several sister societies have cooperated, as in the past, to make the convention a veritable National Metal Congress. American Welding Society had the most extensive program, lasting all week and including eight technical sessions, many inspection trips, and an annual banquet. Features of the program were discussions about steel for residence construction, on metal overlays, on qualifying operators for important work, on research, and on railroad applications.

The American Institute of Mining and Metallurgical Engineers, through its Institute of Metals Division and Iron and Steel Division, also cooperated with notable sessions. In addition to considering various problems of a more theoretical nature, a whole day (and an evening dinner) was devoted by the Institute of Metals to the problems of die casting; a resume of some important facts brought out is given on pages 26 to 29. Two sessions on slag control in steel making were held by the Iron and Steel Division under the energetic leadership of L. F. Reinartz, chairman of the Division — an important matter which will be summarized in the next issue of METAL PROGRESS.

The Wire Association also joined with the National Metal Congress for the third successive year. Formal meetings were held on three days discussing the problems of galvanizing, braiding, and other methods of covering, the drawing of copper wire, and the manufacture of spring wire. The Wire Association Medal was awarded to E. J. P. Fisher.

It is greatly to be regretted that more engineers did not attend the two sessions sponsored by the Machine Shop Practice Division of the American Society of Mechanical Engineers. The time was placed at 5:30 in the afternoon, so that men could hear the program between work and dinner. One meeting was addressed by Zay Jeffries, consulting metallurgist for Aluminum Co. of America, and the other by R. S. Archer, metallurgist, Republic Steel Corp. As everyone had a right to expect, these two experts gave a notable resume of non-ferrous and ferrous metals, today and tomorrow. For the benefit of their fellow members in the American Society for Metals, METAL PROGRESS will publish as much of these papers as space permits in next January's issue.

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S.A.E. 1020 Steel carburized at 1650° to 1675° F. (898° to 912° C.) for 120, 80 and 40 minutes, left to right respectively. Magnification, 6 diameters.

The Process that nearly "stole the show" last month

There was enormous interest in the Perliton Carburizing Process at the National Metal Exposition in New York last month. To many metallurgists it was "new"—yet we would emphasize that it is not new in the sense that it is untried. On the contrary, Perliton Liquid Carburizer has been used with great success abroad for two years, and by more than a score of heat treaters in this country for many months. It meets their demands for rapid, uniform penetration, low cost, long pot life, high thermo-conductivity and absence of decarburization. Write us at 240 W. Somerset St., Philadelphia, for the Perliton book describing this process.

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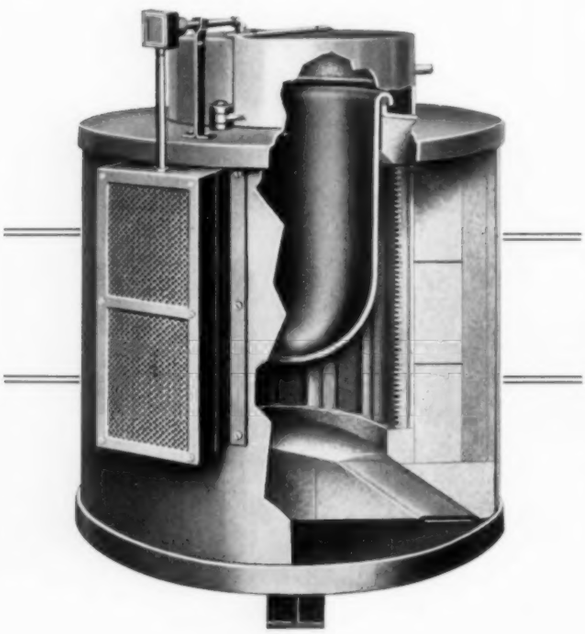

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